United States
Department of
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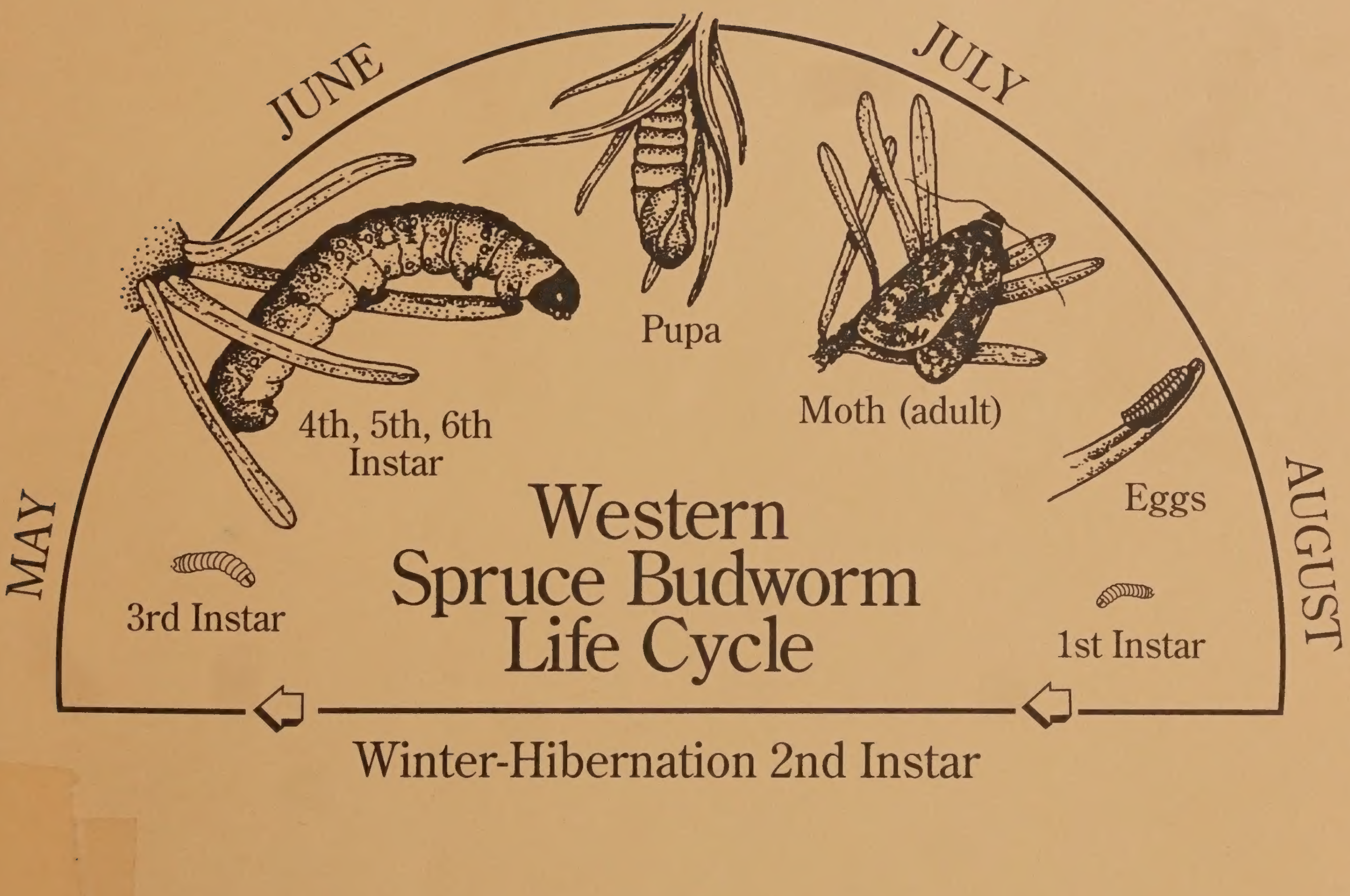
Forest Service

Forest Pest
Management

**Pacific
Northwest
Region**

Draft Environmental Impact Statement

Management of Western Spruce Budworm in Oregon and Washington



Draft Environmental Impact Statement for

Managing Western Spruce Budworm In Oregon And Washington

USDA Forest Service
Pacific Northwest Region
States of Oregon and Washington and Portions of California and Idaho

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Abstract

The Forest Service, in compliance with the National Environmental Policy Act of 1969, is presenting four alternative methods of managing the western spruce budworm in the Pacific Northwest on lands administered by the Forest Service, Bureau of Land Management, Bureau of Indian Affairs, and on private lands in cooperation with the States of Oregon and Washington in federally funded cost-share programs.

The proposed alternatives are:

A) No action, manage the western spruce budworm infestation without the use of insecticides.

B) Direct suppression with the use of the biological insecticide *B.t.* only. This alternative allows the Forest Service to cost-share with States using *B.t.*, but not the insecticide carbaryl.

C) Direct suppression with the use of chemical insecticides only. This alternative allows the Forest Service to cost-share with States using the insecticide carbaryl.

D) Direct suppression with the use of *B.t.* or the chemical insecticide carbaryl. This alternative allows the Forest Service to cost-share with States using both *B.t.* and carbaryl.

The effects of the alternatives on the physical and biological environment, human health, social and economic conditions, and resource management are presented.

Note to Reviewers:

To enable the Forest Service to fully analyze and use all information acquired during the review of the Environmental Impact Statement (EIS), reviewers need to provide their comments during the established review period.

According to a court-established precedent, reviewers participating in the National Environmental Policy Act (NEPA) process must alert the Agency to their positions and contentions in a meaningful way. Another legal precedent, also important to those participating in the review, established that environmental objections which could have been raised at the draft stage, may be waived if they are not raised until after completion of the Final Environmental Impact Statement (FEIS).

Thus, to address all concerns, comments on the DEIS should be timely, thorough, and specific. To be most helpful, comments should address the adequacy of the Statement or the merits of the alternatives discussed.

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Moth (adult)

SUMMARY

Introduction

The Pacific Northwest Region (Region 6) of the USDA Forest Service is headquartered in Portland, Oregon. It includes Oregon, Washington, and parts of a few Counties in California and Idaho. In Region 6, the Forest Service administers 19 National Forests (including 1 National Grassland) totaling 24.5 million acres.

Terrain and vegetation vary widely across the Region. There is a great variety of landforms, from coastal dunes and flat grasslands to rolling hills, steep ridges, mountains, and volcanoes. Natural vegetation ranges from the Olympic rain forest to interior high deserts.

Managing the current outbreak of the western spruce budworm, affecting 19 National Forests in the Pacific Northwest, is a major effort.

This summary of the Environmental Impact Statement (EIS) discusses the issues and concerns raised by the public and other agencies, and Forest Service personnel regarding management of the current western spruce budworm infestation. The summary also describes the purpose and need for the proposed action, and explains how the major issues and concerns identified have been formulated into planning questions. It describes how four differing alternatives respond to these planning questions, and gives the environmental consequences implementing each.

After carefully considering comments from the public, scientists, and Government agencies , a Final Environmental Impact Statement (FEIS) will be prepared and issued. That final version will be the basis for selection of a program for managing future western spruce budworm infestations In National Forests in the Pacific Northwest.

Managing Forest Insects

Insects are part of forest ecological systems. They may play useful, as well as harmful, roles in those systems. Thus, an understanding of each ecological system is essential for effective management of forest insects, and is also necessary for long-term beneficial use of these insects.

Current Situation

Plant communities, Douglas-fir, Western larch, grand fir, white fir, Englemann spruce, and subalpine fir, on the east side of the Cascade Range have been experiencing an ongoing infestation of western spruce budworm. Although western spruce budworm is always present in the forest, epidemic levels of activity have been reached and the associated damage has caused considerable concern to landowners, recreationists, and other National Forest users. The current western spruce budworm outbreak now encompasses millions of acres and is expected to continue in size and intensity. Efforts to control the current infestation could have important consequences on the social, biological, and physical environment. This Environmental Impact Statement (EIS) examines those environmental impacts.

Decision Needed

The decision needed in this EIS is how to manage the current spruce budworm outbreak. During investigation of possible actions and their predictable environmental effects, four alternative programs were developed for managing the current outbreak of the western spruce budworm on lands administered by USDA Forest Service, Bureau of Land Management, Bureau of Indian Affairs, and State and private lands in Oregon and Washington. The EIS displays the environmental impacts and management implications of these four alternatives.

This EIS is presented in draft form to provide an opportunity for public review and comment. After carefully considering comments on this draft from scientists, Government agencies, and the public, a Final Environmental Impact Statement (FEIS) will be prepared and issued. The Regional Forester will use the FEIS as a basis for indicating the Regional Forester's Preferred Alternative.

Description Of The Insect

The western spruce budworm (*Choristoneura occidentalis* Freeman) is a native insect species. It is the most widely distributed and potentially destructive insect of coniferous forests in western North America. The western spruce budworm is one of nearly a dozen species, subspecies, or forms of a spruce budworm complex found throughout the western, north-central, and northeastern United States, and in several western and maritime Canadian provinces. The genus is also represented in Europe.

In Oregon and Washington, the budworm completes one cycle of development from egg to adult within 12 months. Following flight in late July and August, the adult moths lay eggs that soon develop into tiny larvae which overwinter in an inactive state in sheltered places, under bark scales, and in or among lichens on tree boles or limbs. In early May to late June, larvae emerge and begin their active feeding stage. As rapidly growing larvae, spruce budworms molt (shed their skin) a total of five times. The six intervening stages are called instars. After about 30 to 40 days, larvae develop into pupae. The moths emerge from the pupae after about 10 days to begin the cycle again.

The most common host tree species are Douglas-fir, grand fir, and white fir. Host species include subalpine fir, Engelmann spruce, western larch, lodgepole pine, and ponderosa pine. On most host tree species, western spruce budworm larvae feed as typical defoliators. Though preferring succulent new foliage, they also feed on older foliage when new foliage is in short supply or is not available. By the time larvae reach maturity in early to mid-July, they often have consumed or destroyed much of the new foliage on host trees.

Western spruce budworm larvae also feed on the cones and seeds of several species of host trees, particularly Douglas-fir (Dewey, 1970) and western larch (Fellin and Shearar, 1968).

Budworm populations are usually regulated by several natural factors such as parasites, predators, and adverse weather, especially when populations are low (Dewey, 1974). Starvation can also be an important mortality factor in regulating populations during prolonged outbreaks. More than 40 species of parasites are known which attack the budworm larval stage, but none has been found to have much effect on high budworm populations during an outbreak (Torgersen et al., 1984).

Public Involvement

There has been public involvement throughout development of this EIS. To help identify issues, concerns, and opportunities, a mailing requesting comments and concerns was distributed to approximately 2,000 addresses. One press release was mailed to the media in the affected areas.

A total of 209 responses were received through distribution of the scoping brochure and included approximately 550 comments. These comments were analyzed to determine whether they brought up new issues, proposed new alternatives not already considered, or proposed different analysis criteria to evaluate the possible alternatives.

Major Issues And Concerns

Beginning in 1981, and continuing through successive years of environmental analyses (EAs), numerous concerns have been expressed about the current western spruce budworm outbreak, and associated spray programs, in the Pacific Northwest. As the number of infested acres increased, the number of concerns grew, reflecting the opinions of individuals, organizations, and land managers. The issues and concerns developed during the 1984 northeastern Oregon analysis were used as a starting point to build upon during 1985. The public involvement steps used for scoping in 1986 included meetings and written inquiries. In 1986, 1987, and 1988, some additional public meetings were held by individual Forests. In addition, interested parties were solicited in writing for additional issues and concerns that were not addressed in prior EAs. Public meetings, personal consultations, news clippings, and correspondence resulted in identification of public issues and management concerns. These items reflected the views of concerned individuals, forest-based industries, landowners of various-sized forest holdings, forest resources user groups, conservation and environmental groups, Indian tribes, and representatives of local, State, and Federal agencies and governments.

Based on responses to mailings conducted as part of this EIS, and concerns identified in past EAs, eight major public issues were identified. Issues play a substantial role in forming the alternatives, in raising questions for analysis, and in the discussion and rationale for selection of the Preferred Alternative(s).

The eight public issues identified in this document include silviculture; water quality and quantity; fish, wildlife, and domestic animals; economics; human

health; effectiveness of treatment methods; timeliness of treatments; and fuels and fire. A discussion of these issues follows:

Silviculture

The effects on timber production of both treated and untreated budworm outbreaks are quite complex. Long-term management of timber stands through silviculture treatments as a means to end the epidemic is an issue. Therefore, budworm suppression programs would only minimize short-term growth losses. Concern has been expressed that untreated budworm infestations may negate efforts to increase timber growth rates through intensive timber management, and that long-term yields and harvests may be reduced from present levels. Some believe that timber from budworm-caused tree mortality needs to be harvested. Others are concerned the costs of salvaging and reforesting damaged stands far outweigh the costs of direct budworm control. It has been suggested that direct budworm control measures will be needed until timber stands contain healthy mixed species, less vulnerable to budworm infestation.

Water Quality and Quantity

Two broad areas of concern are included in this issue; possible hydrologic changes that might occur in watersheds if the budworm outbreak is left unchecked, and possible contamination of water quality from the use of insecticides. Some members of the public have asserted that widespread defoliation may result in variations to timing and quantity of water yield in heavily affected watersheds; increased flows could result in streambank cutting and greater sediment loads. Hydrologic changes could also affect unstable slopes and cause increased mass failure activity.

Fish, Wildlife, and Domestic Animals

People are concerned that fish, wildlife and domestic animals could be adversely affected to some degree by the budworm infestation or by insecticide control programs.

Big game species may be affected if budworm defoliation changes the quantity and/or quality of coniferous cover used for thermal, hiding, and escape cover. Some people expressed concern that ungulates (deer, elk) may be adversely affected by ingesting insecticides on forage. Since spraying of insecticides usually occurs about the same time as spring birthing, some people expressed concern about the effects of increased human disturbance on this critical biological activity (increased desertion of young, vulnerability to predation).

Economics

The benefits and costs of alternatives being considered for dealing with the budworm outbreak need to be displayed and compared. Many opinions have been expressed regarding factors that should enter into the economic efficiency analysis and the appropriateness of assumptions used in past analyses. Benefits and costs associated with the following factors have been suggested for consideration: timber growth loss, effectiveness of *B.t.* compared to carbaryl, risk of budworm population resurgence and reinvasion of treated areas, risk of future outbreaks in the area, and reduced recreation use.

Concern has been expressed regarding possible reductions in National Forest timber harvest levels because of the budworm outbreak and subsequent effects on employment and community stability.

Human Health

Most people who have expressed concern with budworm control projects want an understanding of hazards associated with the use of the insecticides being considered. The potential for long-term, short-term, and cumulative effects on human health is a concern. Possible effects on pregnant women, children, older people, and chemically sensitive people have been mentioned. Some are disturbed with the amount and type of data available to support decisions regarding the use of insecticides; others disagree with the choice of data and studies used or the conclusions reached by past risk analyses; and some categorically distrust risk assessments conducted by insecticide manufacturers, their contractors, or the Government.

Many of the people showing an interest in budworm control programs expressed a preference for continued use of biological rather than chemical insecticides. There are concerns about cumulative health risks from existing chemical use in the environment, and that additional chemical pesticide applications will add to human health hazards.

Effectiveness of Treatment Methods

The effectiveness of biological insecticides is dependent upon application techniques and proper timing. The efficacy of a biological insecticide is more dependent upon weather conditions than chemical insecticides. Unlike chemical insecticides, biological insecticides must be ingested by western spruce budworm larvae to be effective. The optimum conditions for treatment, therefore, result in a fairly narrow effective spray interval. Treating too early can result in many individual larvae escaping exposure to Bacillus Thuringiensis (*B.t.*) because they are not

feeding on foliage that is exposed to the spray, the effectiveness of *B.t.* can be diminished by exposure to sunlight before being ingested by larvae. Treatment administered too late might result in avoidance of *B.t.* by larvae that have advanced into the late sixth instar and have ceased feeding prior to pupation. Even with the best timing of spray applications, some larvae will survive due to the range of instars present, and the difference in host phenologies (as influenced by site, elevation, and other factors) over the spray block at the time of application.

Timeliness of Treatments

Throughout its range, detectable populations of western spruce budworm appear to persist indefinitely in stands that contain a substantial proportion of suitable hosts. Some feel that immediate suppression action could limit the spread of an infestation and prevent a widespread outbreak.

Wildfire

Many years of effective fire suppression efforts have caused accumulations of needle litter, dead limbs, and dead trees which can lead to high intensity wildfires. Outbreaks of mountain pine beetle, western spruce budworm, and Douglas-fir tussock moth have contributed and are presently increasing fuel loading. However, recent insect epidemics have increased the rate of accumulation.

Planning Questions:

1) What are the economic implications of potential alternatives?

The potential losses in timber growth and yield due to foliage loss are of concern. Visuals are also affected by spruce budworm as foliage becomes red or trees die. This may have an effect on the local economies of small communities dependent, in part, upon recreation income. Spraying and thinning projects bring dollars to the local economy by creating employment opportunities for local citizens, and purchasing goods and services.

2) How effective are available treatment methods in reducing the insect population? (Efficacy)

The efficacy of *B.t.* and other pesticides is directly related to the method of application, weather, and timing. Because *B.t.* is specific to lepidopteran species, there is little likelihood of adverse impacts from the use of *B.t.* on aquatic insects or fish.

3) What are the effects of each alternative on fish, wildlife, and domestic animals?

Concerns that increased human disturbance associated with control projects upon deer and elk during fawning and calving have been raised. Some people feel that fawns and calves would be more vulnerable to predation because of increased chances of desertion by the mothers. Bald eagle nesting territories occur within infested forests. There are concerns about the health effects on wildlife resulting from use of *B.t.* or carbaryl.

4) What is the effect of budworm treatment/nontreatment, on scenic values and recreation use?

Timber stands affected by the current spruce budworm outbreak will suffer various types and degrees of damage to wood fiber production. Treatment would avert most of the future predicted loss of wood fiber production due to the current outbreak.

5) What is the effect of, budworm treatment/nontreatment, on fuel loads and fire management?

As needles drop to the forest floor, the tops of trees die, and fuel loads increase. Due to the current outbreak, what is the likelihood and potential impact of an uncontrolled fire event under the various management options? What is the potential for fire ignition caused by human activities and lightning?

6) What are the hydrologic effects of treatment/nontreatment?

Concerns have been raised regarding the effects of the western spruce budworm infestation upon water quality and quantity. Some feel defoliation and tree mortality influence snowpack levels, seasonal snowmelt, stream temperatures, turbidity, and overland flows.

7) What is the timeliness of treatment for this and future outbreak cycles?

Concerns have been raised about the time lapse between the discovery of the outbreak and the start of treatment. Why isn't treatment effected at the beginning of the outbreak? Some do not understand why the treatment is effective only if applied during a short timeframe in late spring.

8) What are the effects on human health associated with treatment using *B.t.* and other chemicals?

USDA Forest Service Management Objectives

Management direction provided through laws, regulations, and policy, is detailed in a number of

places. The following references contain material applicable to alternatives being considered in this analysis: (These references are available at the USDA Forest Service, Pacific Northwest Regional Office in Portland Oregon).

A. Wilderness, Primitive Areas, and Wilderness Study Areas. Where a choice must be made between Wilderness values and any other activity, preserving the Wilderness resource is the overriding value. Economy, convenience, commercial value, and comfort are not standards of management, or use of Wilderness. Because uses and values on each area vary, management and administrative must be tailored to each area. Even so, all Wildernesses are part of one National Wilderness Preservation System and their management must be consistent with the Wilderness Act and their establishing legislation. This policy states that insect or disease outbreaks will not be artificially controlled unless it is necessary to protect resources outside the Wilderness. Insect or disease suppression projects in National Forest Wildernesses shall be based on factors set forth in FSM 2300 and 3400 and be approved by the Chief of the Forest Service.

B. Oregon and Washington State Forest Practices Act. The Oregon Forest Practices Act provides for a set of rules establishing minimum standards which encourage and enhance the growing and harvesting of trees. At the same time, the Act considers and protects other environmental resources - air, water, soil, and wildlife.

C. Federal Insecticide, Fungicide, and Rodenticide Act of 1972 as amended (Public Law 92-516). Is the authority for the registration, distribution, sale, shipment, receipt, and use of pesticides. The Forest Service may use only pesticides registered or otherwise permitted in accordance with the Federal Insecticide, Fungicide, and Rodenticide Act, as amended.

D. Environmental Protection Agency Regulations. These regulations include air and water quality standards that must be met. The U.S. Environmental Protection Agency (EPA) has responsibility, under a variety of statutes, to protect the quality of the Nation's ground water and air quality, as well as direct responsibility for regulating the availability and use of pesticide products.

E. Endangered Species Act. Plant or animal species identified by the Secretary of Interior as endangered in accordance with the 1973 Endangered Species Act, as amended. The goal of the sensitive species program is to maintain viable populations of sensitive species to ensure they do not become threatened or endangered because of Forest Service actions. Population and/or habitat objectives need to be developed and implemented for most of the species listed by the Regional Forester.

F. Any implemented project will comply with other applicable local, State, and Federal laws, regulations, or policies.

G. Treatments will comply with the direction provided in the most recently approved Land Management Plan for National Forest System lands.

USDA Forest Service Goals

Insect outbreaks will be prevented or suppressed by methods that will restore, maintain, or enhance the quality of the environment. These objectives are attained on non-Federal lands through cooperation with State Foresters or equivalent State officials. Insects are suppressed directly on National Forest System lands and in cooperation with responsible officials on other Federal lands. The Forest Service has cost-share agreements with the States of Washington and Oregon. These agreements allow the Forest Service to pay for a portion of the suppression of spruce budworm on private lands.

A principal U.S. Department of Agriculture goal is to assure an adequate supply of high quality food and wood fiber and a quality environment for the American people. The USDA gives special emphasis to the development and use of efficient and environmentally acceptable integrated pest management systems.

Alternatives

Introduction

This Environmental Impact Statement (EIS) displays four different ways of managing the western spruce budworm, including a No-action Alternative. Each of the three action alternatives utilizes a different treatment with a biological or chemical insecticide, or a combination of both types of insecticides.

Development Of Alternatives

Alternatives Considered But Eliminated From Detailed Study

The Forest Service considered a range of alternatives in order to assess the reasonableness of the

alternatives to be considered in detail. Those alternatives eliminated from detailed study, along with the rationale for their elimination, are as follows:

1. Suppression using biological methods other than *B.t.*

2. Indirect Suppression Using Silvicultural Techniques

3. Suppression Using the Chemical Insecticides Mexacarbate, Acephate, and Malathion.

Alternatives Considered In Detail

Four alternatives were considered in detail for this EIS.

Alternatives B and D are the Forest Service preferred alternatives.

Objectives Used In Designing Alternatives

The issue-driven objectives used in designing all action alternatives include:

1. meeting or exceeding water quality standards;

2. maintaining wildlife habitats and populations;

3. minimizing any potential risks to human health and the human environment;

4. utilizing an effective and economically sound method of management.

Alternative A: (No Action)

This alternative provides no direct suppression action to reduce the western spruce budworm population to nondamaging levels. The budworm infestation would be allowed to continue until it collapses due to natural factors.

Current management practices in the infested areas would continue. Scheduling and timing of these activities could be affected by the budworm outbreak. Silvicultural prescriptions may be changed to respond to forest stand damage.

Western spruce budworm activity would be monitored annually with an aerial sketchmap survey to determine the extent of visible defoliation.

Alternative B (Preferred)

This alternative would provide direct suppression utilizing the biological insecticide *B.t.*

This short-term alternative consists of suppression projects to protect resource values (commodity and noncommodity) that are truly at risk of unacceptable damage. It would involve the aerial application of the biological insecticide *B.t.* to selected areas with the objective of reducing budworm populations to nondamaging levels.

Alternative C

This alternative would utilize direct suppression with the use of chemical insecticides.

This short-term alternative consists of suppression projects to protect resource values (commodity and noncommodity) that are at risk of unacceptable damage. Four chemical insecticides, malathion, acephate, mexacarbate, and carbaryl, are currently registered by the Environmental Protection Agency for suppression of western spruce budworm by aerial application. This alternative discusses only the use of carbaryl. At this time, carbaryl is the most acceptable chemical insecticide in terms of efficacy in suppressing budworm populations. Application of carbaryl would involve aerial broadcast treatment of infested areas, while leaving at least a one-swath untreated (buffer) strip on either side of streams and around bodies of water. The objective would be to reduce budworm populations to nondamaging levels for at least a major portion of the current outbreak.

Alternative D: (Preferred)

This alternative would combine the use of *B.t.* and the chemical insecticide carbaryl.

This short-term alternative consists of suppression projects to protect resource values (commodity and noncommodity) that are at risk of unacceptable damage. This would include the use of *B.t.* up to, but not over streams or other bodies of water. Carbaryl would be used up to a buffer strip along streams or around other bodies of water. *B.t.* could be used in the buffer strips. The choice of carbaryl or *B.t.* over the majority of the treatment area would be determined on a project-specific basis. The particular attributes of each area, including amounts of sensitive areas and humans habiting or frequenting the unit, would be considered in the decision.

A comparison of these alternatives follows:

Comparison Of Alternatives

Planning Question #1:

What are the economic implications of the alternatives?

Alt. A. (No Action)	Long-term reduction in future supply of wood fiber; short-term increase of logs for manufacturing due to salvage operations.
Alt. B. (Use of *B.t.* only)	Long-term supply of wood fiber maintained; short-term increases in expenditures to local economies for services rendered.
Alt. C. (Use of Carbaryl only)	Long-term supply of wood fiber maintained; short-term increases in expenditures to local economies for services rendered.
Alt. D. (Use of both *B.t.* and Carbaryl)	Long-term supply of wood fiber maintained; short-term increases in expenditures to local economies for services rendered.

Planning Question #2:

How effective are the treatment methods?

Alt. A. (No Action)	No effect on achieving lasting budworm population reductions.
Alt. B. (Use of *B.t.* only)	Applications are likely to suppress budworm populations below identified threshold levels; populations unlikely to develop a tolerance; resurgence and reinvasion are not anticipated.
Alt. C. (Use of Carbaryl only)	Applications are likely to suppress budworm populations below identified threshholds; budworm populations can develop a tolerance to carbaryl applications; reinvasion may occur from streamside buffer strips; resurgence is a potential problem.
Alt. D. (Use of both *B.t.* and Carbaryl)	Flexibility to utilize both *B.t.* and/or carbaryl as the situation warrants, is likely to suppress budworm populations below identified threshhold levels; reinvasion need not occur; resurgence may occur.

Planning Question #3:

What are the effects of alternatives on other resources?

Alt. A. (No Action)	Implementation of this alternative would not produce adverse impacts to other resources.
Alt. B. (Use of *B.t.* only)	Implementation of this alternative would not produce significant impacts to other resources. Some resources such as general wildlife populations, may benefit slightly.
Alt. C. (Use of Carbaryl only)	Implementation of this alternative may produce significant impacts to some resources. Specifically, some species of small mammals, birds, and insects may

be adversely affected by the toxological properties of carbaryl.

Alt. D. (Use of both *B.t.* and Carbaryl)	Implementation of this alternative, correspondent with established mitigation measures, may result in minor impacts to some resources. Significant impacts would probably be mitigated by the use of B.t. in sensitive ecosystems.

Planning Question #4:

What is the effect of each alternative on visual quality?

Alt. A. (No Action)	Severe defoliation will result in color and texture changes for up to a decade or more; changes to visual quality could result in decreased recreational use, with a coresponding impact on the recreation economy.
Alt. B. (Use of *B.t.* only)	Treatment would provide short-term protection of foliage; changes to color and texture of the landscape are reduced but not eliminated; cumulative mortality and top-kill would be reduced; only slight reductions in recreation user days would be expected; a forest with tree species susceptible to continued defoliation would be maintained.
Alt. C. (Use of Carbaryl only)	Treatment would provide short-term protection of foliage; changes to color and texture of the landscape are reduced but not eliminated; cumulative mortality and top-kill would be reduced; only slight reductions in recreation user days would be expected; a forest with tree species susceptible to continued defoliation would be maintained.
Alt. D. (Use of both *B.t.* and Carbaryl)	Treatment would provide short-term protection of foliage; changes to color and texture of the landscape are reduced but not eliminated; cumulative mortality and top-kill would be reduced; only slight reductions in recreation user days would be expected; a forest with tree species susceptible to continued defoliation would be maintained.

Planning Question #5:

What is the effect of alternatives on fuels and fire?

Alt. A. (No Action)	Minimal impact on fuel loading in areas where only scattered mortality has occurred; severe defoliation and continuous mortality will result in significant increases to fuel loading; fire intensity is expected to be high; fire line construction will be slow.
Alt. B. (Use of *B.t.* only)	Short-term potential for heavy fuel buildup would be reduced or eliminated; scattered mortality would occur; existing fuel loadings would not be significantly increased; projected fire intensity and fireline construction rates would not be slowed.
Alt. C. (Use of Carbaryl only)	Short-term potential for heavy fuel buildup would be reduced or eliminated; scattered mortality would occur; existing fuel loadings would not be significantly increased; projected fire intensity and fireline construction rates would not be slowed.
Alt. D. (Use of both *B.t.* and Carbaryl)	Short-term potential for heavy fuel buildup would be reduced or eliminated; scattered mortality would occur; existing fuel loadings would not be significantly increased; projected fire intensity and fireline construction rates would not be slowed.

Planning Question #6:

What are the hydrological effects of treatment and nontreatment?

Alt. A. (No Action)	No significant increase in annual streamflow or peak discharge is anticipated as a direct result of defoliation and mortality. Cumulative impacts from defoliation and extensive management activities could produce significant increases in annual streamflow. These increases could degrade water quality. Defoliation and mortality could promote slight increases in water temperature in some stream segments.
Alt. B. (Use of *B.t.* only)	This alternative would reduce defoliation while minimizing impacts described in the No-action Alternative.
Alt. C. (Use of Carbaryl only)	This alternative would reduce defoliation while minimizing impacts described in the No-action Alternative.
Alt. D. (Use of both *B.t.* and Carbaryl)	This alternative would reduce defoliation while minimizing impacts described in the No-aAction Alternative.

Planning Question #7:

What is the timeliness of treatment for this and future outbreak cycles?

Alt. A. (No Action)	Implementation of this alternative would allow the budworm infestation to follow its natural course. It would have no effect on the frequency of future outbreak cycles.
Alt. B. (Use of *B.t.* only)	Implementation of treatments prescribed in this alternative is timely. Sufficient time has elapsed to indicate that the outbreak is persisting despite natural enemies. Earlier treatment would not have prevented the "spread" of budworm infestation. The application of *B.t.* should have no effect on future outbreaks.
Alt. C. (Use of Carbaryl only)	Implementation of treatments prescribed in this alternative is timely. Sufficient time has elapsed to indicate that the outbreak is persisting despite natural enemies. The application of carbaryl (with buffers where appropriate) may have an effect on the ability of budworm populations to reinvade and resurge, thus affecting future outbreaks.
Alt. D. (Use of both *B.t.* and Carbaryl)	Implementation of treatments prescribed in this alternative is timely. Sufficient time has elapsed to indicate that the outbreak is persisting despite natural enemies. The application of sublethal dosages of carbaryl may stimulate budworm populations and contribute to the resurgence of vigorous populations.

Planning Question #8:

What are the effects on human health associated with treatments using *B.t.* and other chemicals?

Alt. A. (No Action)	This alternative would have no effect on human health since the alternative does not employ chemical insecticides or biological controls.

Alt. B. (Use of *B.t.* only)	This alternative presents the least risk of the direct suppression alternatives. The use of *B.t.* poses little risk of acute or chronic effects upon human health.
Alt. C. (Use of Carbaryl only)	This alternative presents the highest risk to human health of the direct suppression alternatives. Carbaryl poses a human health risk only in the case of accidents. The petroleum distillate carrying agents (kerosene and diesel oil) commonly used for application present a risk under routine worst-case conditions, and in the case of accidents.
Alt. D. (Use of both *B.t.* and Carbaryl)	This alternative presents human health risks of an intermediate nature. Risks would be reduced to the extent that *B.t.* is used instead of carbaryl.

Affected Environment

Location

The Pacific Northwest Region (Region 6) includes the States of Oregon and Washington, as well as small portions of northern California and western Idaho. The region covers a total area of 106 million acres. The USDA Forest Service administers 24.5 million acres of this area, divided into 19 National Forests and 1 National Grassland. The Forest Service also assists in the protection and management of 20.5 million acres of other commercial forest lands through cooperative programs with private landowners, and State and local governments.

Water Quality and Quantity

The National Forests occupy 23 percent of the land in the Pacific Northwest, yet 44 percent of the region's water supply originates on National Forest land.

About 6 million acres, approximately one quarter of National Forest lands, are managed specifically as domestic watersheds. About 800,000 acres are managed according to formal agreements with fifteen municipalities. The quality and quantity of water produced by National Forests is dependent upon the management of vegetation and soils in each watershed.

Plant Communities

All true fir and Douglas-fir stands are potential hosts for western spruce budworm. The current epidemic is located primarily on the east side of the Cascade Range.

Over the last century, the vegetative composition of National Forests has changed greatly. These changes are especially evident on the East-side Forests. Heavy grazing by horses, sheep, and cattle at the turn of the century tended to increase the early stages of forbs and grasses. Aggressive fire prevention and suppression practices over the past 80 years helped to convert open grasslands to tree-growing sites, and open pine stands to thickets of mixed conifer species. In other areas, the late seral stages of tree species were greatly increased later in the 1950's and 1960's by logging practices which selectively removed the ponderosa pine.

The change in species composition from ponderosa pine to white fir or Douglas-fir is accompanied by increased susceptibility to insects and disease. Insects and disease are not new to the forests, but as their host types increase, the potential for their occurrence also increases.

The increase in host type is not the only factor in the current western spruce budworm outbreak. Most of the understory stands of white fir and Douglas-fir have been suppressed by the ponderosa pine overstory. Removal of the pine overstory has not released the firs to grow freely. The shade-tolerant understory is overstocked and unthrifty. The poor health of these stands, compounded by the present drought cycle, has resulted in thousands of acres of susceptible host trees.

Insect-caused tree mortality on the forests has been heavy during the past 20 years. Primary causal agents have been Douglas-fir tussock moth, mountain pine beetle, and western spruce budworm. Currently, western spruce budworm and mountain pine beetle are causing the largest amount of mortality.

Timber

Much of the land within the National Forests of the Pacific Northwest Region is among the most productive forest land in the world. Roughly 90 percent of National Forest lands are forested.

Demand for timber will vary with market and economic conditions, and is affected by short-term decisions of other industrial and agency forest ownerships. As a general situation, however, there are purchasers for all volumes made available for harvest. Recent trends of both harvest levels and acres available for regulated harvest (the systematic removal of products) are reflected in Forest land management planning processes. While conditions vary from Forest to Forest, the trend is for somewhat reduced programmed harvest levels in comparison with recent historic levels.

Wildlife and Wildlife Habitat

Forests of the Pacific Northwest Region are known to provide habitat for 569 species of resident and migratory, terrestrial vertebrate wildlife (174 mammals, 335 birds, and 60 reptiles and amphibians).

In order to maintain viable, self-sustaining populations of wildlife, an appropriate amount and distribution of suitable habitat must exist. The amount and distribution of habitat will vary over time. Changes in habitat condition and suitability can occur abruptly (as the result of fire, windstorm, or timber harvest), or more gradually (as in the slow replacement of plant communities characteristic of succession).

In the absence of human manipulation, natural landscapes support characteristic patterns of plant communities and stand conditions. These reflect, in

part, the frequency of disturbances, site productivity, and successional changes that occur over time.

Threatened, Endangered, and Sensitive Animal Species

Six wildlife species currently listed by the U.S. Fish and Wildlife Service as endangered or threatened under the Endangered Species Act are known or suspected to occur on National Forest lands in the Pacific Northwest.

These species differ widely in their distribution in the Northwest. The brown pelican is known only from coastal portions of the Siuslaw National Forest. Woodland caribou occur only on the Colville National Forest. In the State of Washington, grizzly bear and gray wolf have documented or suspected occurrences in four and five Forests, respectively. Peregrine falcons are known or suspected to occur on all but three National Forests in the Region, and the bald eagle is known to have nesting, winter roosting, or migratory sites on all 19 Forests.

Thirty-six other species (8 mammals, 14 birds, 1 reptile, 3 amphibians, and 10 fish) are included on the Regional list of Sensitive Species. All Forest Service activities that might disturb these species or their habitat must be preceded by a biological evaluation (Forest Service Manual 2670).

Threatened, Endangered, and Sensitive Plant Species

On National Forest lands in Oregon and Washington, only one plant species currently listed under the Endangered Species Act is known to occur. MacFarlane's four-o'clock (*Mirabilis macfarlanei*) is listed as endangered. It is known to occur at only a few locations in the Snake River country of Oregon and Idaho.

Fisheries

The Pacific Northwest Region has approximately 15,000 miles of streams that directly support both resident and anadromous fish. There are approximately 150,000 acres of lakes and 65,000 acres of reservoirs that can support both warm and cold water species of fish.

Resident game fish include rainbow, eastern brook, Dolly Varden, and cutthroat trout; crappie; bluegill; yellow perch; smallmouth and largemouth bass; Kokanee; and mountain whitefish. Anadromous fish (fish that spawn in fresh water and migrate to the ocean to mature) have both sport and commercial value. They are found on 15 of the 19 Forests in the Region.

Insect (management) activities have the potential to affect fish habitat characteristics such as water temperature; sediment load; turbidity; water quantity, timing of flows; and the character of streamside vegetation. The quality of fish habitat is dependent upon management practices within watersheds.

Visual Resources

Scenic diversity in the Pacific Northwest Region contributes greatly to the recreational value of the Forests. A few examples of this diversity include coastal forests, jagged peaks in the North Cascades, the high desert of central Oregon, moss-draped trees in the Olympic rain forest, and the Blue Mountain and Snake River areas.

The landscape management objective is to manage all National Forest System lands to attain the highest possible visual quality compatible with other appropriate public uses, costs, and benefits. In order to comply with the objective, the USDA Forest Service developed the Visual Management System.

Sightseeing is an important component of Forest recreational activities. Most of this activity occurs along major road, trail, and river corridors. Areas that can be seen from these travelways are called viewsheds.

Natural agents can also have a negative effect on visual quality. Wildfire, wind, insects, and disease are among natures causal agents. The eruption of Mount St. Helens had a vast impact on thousands of acres.

Recent examples of insect infestation effects on visual quality are the lodgepole stands suffering from the current mountain pine beetle attack on the Deschutes National Forest, and the tussock moth epidemic in the 1970's on the Wallowa-Whitman National Forest. At the present time, a widespread western spruce budworm infestation is resulting in millions of acres of dead foliage and trees in eastern Oregon and Washington.

Wildfire

Fire, and its exclusion, has been a significant factor in the development of plant communities on the National Forests, especially on the east side of the Cascades. All vegetational types have developed subsequent to fires of natural origin. The frequency and intensity of those fires has, to varying degrees, determined the species of trees present on different sites.

The National Forests have continued to operate under an aggressive fire suppression policy, taking

immediate control action on all unplanned ignitions. This policy of fire suppression has had unexpected side effects. One effect is a decades-long buildup of fuels in some areas. A second effect is that vegetation types have also been changing.

Social and Economic Conditions

The area of influence for the purposes of this report--the people and communities most directly influenced by National Forest management activities and outputs of the Pacific Northwest Region--comprises the States of Oregon and Washington. The major geological feature is the Cascade Mountain Range, which parallels the Pacific coastline about 100 miles inland. This rugged range divides the region into two distinct zones, west and east. Climate, vegetation, the economy, and population patterns are different on the west and east sides of the Cascades.

The western part of the region has 5.7 million people. It contains the majority of the population of the two States. Eighty-seven percent of Oregon's population, and 69 percent of Washington's reside west of the Cascades. The economy in the western portion of the region is relatively diversified; more so in Washington than in Oregon.

The eastern part of the region covers two-thirds of the land area of Oregon and Washington. It contains a smaller proportion of the population: about 13 percent of Oregonians and 31 percent of Washingtonians live east of the Cascade Mountains. The economy of the eastern portion of the region depends more on agriculture, forest products industries, and the livestock industry than does the western portion.

Land Uses

Landownership patterns within the Pacific Northwest Region of the Forest Service are highly complex around and within National Forest boundaries. Many of the private holdings are managed for timber production by private industrial owners. State and Federal agencies (the Oregon Department of Forestry, Washington Department of Natural Resources, and the USDI Bureau of Land Management, for example) also manage large tracts of land within and adjacent to the boundaries of the Region.

Public Health

The States of Oregon and Washington had a combined population of approximately 7 million people as of 1984. People in the region enjoy above-average good health, compared to the total U.S. population. The Forest Service reports a trend of increasing numbers of residents living near National Forests. This increasing proximity of people living near lands managed by the Forest Service has resulted in increasing public concern with environmental issues such as air and water quality, and public health.

Environmental Consequences

Estimating Environmental Consequences

Environmental consequences (or effects) occur when ecosystems are changed---whether through management action or inaction. This chapter presents the environmental consequences of the no action and action management alternatives.

In addition to this EIS, if an action alternative is selected, project-specific environmental analysis will be required before project implementation.

Water Quality/Quantity

Based upon the maximum anticipated basin defoliation rates projected for a spruce budworm infestation, and the similarity between tussock moth and spruce budworm infestations, no significant increase in streamflows or peak discharges should result solely from spruce budworm impacts. However, significant increases in annual streamflow could result from the cumulative impacts of a severe budworm defoliation and management activities.

Alternative A

Alternative A, the No-action Alternative, should have minimal impacts on water quality and quantity.

Alternatives B, C, and D

Implementation of Alternatives B, C, and D would reduce defoliation and eliminate the slight impacts described in the No-action Alternative. Also, that portion of a cumulative impact attributable to defoliation would be removed.

Mitigating Measures

Aerial insecticide application near streams and open water is controlled by State law.

A buffer zone will be left adjacent to streams, lakes, wetlands, and other waterways when applying

carbaryl. This buffer strip must be at least one swath wide.

Vegetation

Alternative A

The No-action Alternative, over time, would open pockets in the tree canopy due to mortality. The cumulative effect of this alternative would be a gradual change of stand structure over time.

Alternatives B, C, and D

The action alternatives would tend to keep stands and attendant plant communities in their present state of development.

Timber

Timber stands affected by the current spruce budworm outbreak suffer various types and degrees of damage to wood fiber production. The most measurable result is growth loss.

Potential for Growth Loss

Alternative A

A major impact of budworm defoliation on a timber stand is growth loss. Under the No-action Alternative, the maximum amount of budworm-caused growth loss would continue until the population collapsed due to natural regulating factors, or until a subsequent analysis determined that suppression measures were needed. In the long term, as the host trees are replaced by more resistant species, growth loss due to the infestation would become less.

Cumulative effects on timber would be a continuing and expanding loss of fiber production until the outbreak cycle collapsed or stand replacement occurred.

Alternatives B, C, and D

Projections show that implementation of these alternatives would result in a level of budworm population control that would avert most additional loss of wood fiber production due to the current outbreak. Cumulative effects on timber production would be a reduction in volume lost due to reduction of height growth and mortality.

Alternative A

Harvest volume impacts due to tree mortality will depend upon both the intensity and duration of the infestation. Scattered mortality may be beneficial in some instances. Mortality of budworm host trees may actually accelerate the growth of nonhost trees.

Under this alternative, forests would exhibit a maximum amount of mortality caused by an outbreak allowed to continue until collapse due to natural regulating factors.

Alternatives B, C, and D

With the action alternatives, there would be very little budworm-caused mortality in undamaged stands.

Potential for Top-kill and Deformity

Alternative A

In general, assessments of top-kill have shown its frequency to vary among and within stands. Under the No-action Alternative, the maximum amount of top-kill and deformity caused by a full-term budworm outbreak would be experienced.

Alternatives B, C, and D

Under these alternatives, top-kill and deformity due to budworm damage as described in Alternative 1, could be averted in stands which have not yet experienced top-kill.

Insect Complex

Because of uncertainties about western spruce budworm behavior and population dynamics, the ability to achieve a lasting reduction in budworm populations is a concern. The following discussion addresses six categories of uncertainties identified during scoping for this analysis; the outbreak cycle, reinvasion, resurgence, timing, tolerance, and efficacy:

Outbreak Cycle

Two conditions currently believed to cause outbreaks of the western spruce budworm are an abundant food supply (extensive stands of Douglas-fir and true firs) and favorable weather (Fellin et al., 1983).

Human intervention in the ecosystem through timber harvesting practices and control of wildfires has led to large acreages of true fir and Douglas-fir (West, 1969; Hall, 1980; Schmidt, 1981). This readily available food source, combined with favorable (warm and dry) weather during May, June, and July, can lead to an outbreak (Hard et al., 1980; Ives, 1981; Twardus,

1982). Natural enemies, such as parasites and predators, both vertebrate and invertebrate, apparently exert little control over budworm populations moving into an epidemic situation (Miller and Renault, 1976; Ives, 1981; Campbell and Torgersen, 1982; Torgersen et al., 1984).

Prolonging a budworm outbreak or increasing the frequency of outbreaks through the use of insecticides is potentially a problem but is insignificant in comparison to the proliferation of extensive areas of the preferred hosts (Blais, 1983; Fellin, 1983).

Reinvasion

It is reasonable to assume that in the absence of substantial geographic barriers or breaks in host-type, adult moths will move freely in their search for host plants.

Resurgence

The third uncertainty is whether budworm populations, reduced by treatment, remain at low levels or build back up (resurge) to outbreak numbers. The lower the budworm population densities are suppressed and the least impact on natural enemies, the higher the probability the population will not resurge.

Timing

Throughout its range, detectable populations of budworm appear to persist indefinitely in stands that contain a substantial proportion of suitable hosts. Treating early in an outbreak does not prevent "spread" of budworm.

Tolerance to Insecticides

The development of population tolerance to insecticides generally requires heavy selection pressure from the repeated use of a particular insecticide.

It is generally considered difficult for insects to develop resistance to microbial insecticides, such as *B.t.*, because of their complex modes of action.

Efficacy

Aerial application of insecticides is very complex because there are so many variables that are uncontrollable. Differences in elevation, slope,and aspect result in varying times of insect and foliage development over an area. Careful attention to each of these variables increases the probability of budworm larvae consuming a lethal dose of insecticide.

Alternative A

Use of the No-action Alternative has no effect on achieving lasting budworm population reductions. Use of this alternative does not preclude the long-range prevention of budworm outbreaks through current and future forest management practices.

Alternative B

Applying *B.t.* is not considered likely to prolong the outbreak. Application should have no effect on natural enemies. When populations of budworm are suppressed, the natural enemies should be able to again exert their controls.

Quality *B.t.* applications are likely to suppress budworm populations below the established threshold of less than an average of 1 larva per branch tip.

Alternative C

Applying carbaryl is not considered likely to prolong the outbreak, and should have only minor effects on natural enemies.

Reinvasion from untreated areas within the treatment areas is a potential problem.

Resurgence is a potential problem with carbaryl.

The use of carbaryl would not affect the timing of treatment of damaging populations.

Studies show budworm populations can develop a tolerance to carbaryl applications.

Quality carbaryl applications are likely to suppress budworm populations below the established threshold of less than an average of 1 larva per branch tip.

Alternative D

Selection of either *B.t* or carbaryl would allow managers to use the one in a particular situation which best meets the needs of a particular situation. When there is no practical difference, or no concern about potential effects, the choice may be made on economic or other reasons.

Wildlife

Alternative A

Taking no action, and allowing continued spruce budworm infestation, will result in minor reductions of hiding and thermal cover for big game. Offsetting these losses will be an increase of forage production associated with reduced tree crown cover. Both effects are expected to be of little consequence.

Beneficial effects include slight increases in nesting habitat for cavity nesters and perches for raptors as a result of tree mortality and top-kill. Overall, it appears general wildlife populations benefit slightly from the current spruce budworm infestation. Benefits are transitory and are not expected to last much longer than the infestation.

Alternative B

Impacts upon wildlife result primarily from increased human activity associated with treatment projects. Coverage of large areas by personnel and equipment increases the disturbance factor.

Field tests have not revealed any deleterious effects of *B.t.* on populations of birds and mammals.

Except for lepidopterans, no toxicity to zooplankton, arthropods, fish, birds, mammals, and other wildlife or domestic species, has been demonstrated at levels recommended for field application.

Since *B.t.* is not a broad-spectrum insecticide and affects only lepidopterans (moths and butterflies), expected impacts upon terrestrial organisms are slight. Most beneficial insects would not be affected.

Alternative C

The risk to wildlife species from spruce budworm suppression with carbaryl is a function of the inherent toxicity (hazard) of the insecticide to different organisms, and the amount of chemical (exposure) those organisms may take in as a result of a spraying operation.

For wildlife risks, the criteria used by the Environmental Protection Agency (EPA, 1986) in ecological risk assessments were used to judge absolute risks to the different representative species. Because carbaryl showed no tendency to bioaccumulate, long-term persistence in food chains and subsequent toxic effects, such as those resulting from use of persistent organochlorides, are not considered a problem.

Wildlife Risk Overview

In general, based on available toxicity data and proposed application rates, risks to wildlife are low to negligible in the spruce budworm suppression program.

Carbaryl

No realistic or extreme doses of carbaryl exceed the EPA risk criterion. Alternative C would not present a risk to wildlife.

Diesel Oil and Kerosene

Wildlife exposures are far below the EPA risk levels for these two chemicals and, under this program, there would be no risk to wildlife from their use.

Invertebrates

Aquatic insects in the orders Plecoptera (stoneflies) and Ephemeroptera (mayflies) are highly sensitive to low levels of carbaryl. Trichoptera (caddisflies) and Diptera (true flies) are also sensitive to carbaryl.

Carbaryl

Mammalian Toxicity

Carbaryl is considered moderately toxic to mammals and slightly toxic to birds.

Avian Toxicity

Results of carbaryl studies on birds vary. A number of studies have reported no effect on bird populations in areas treated with carbaryl. One study reported significant declines in bird populations, possibly resulting from reduced food supplies.

Effects on Avian Reproduction

Studies indicate the possibility that extensive use of carbaryl may cause a significant reduction in reproductive success of avian species, especially quail and pheasant.

Toxicity to Honey Bees

Carbaryl is very toxic to honey bees (Union Carbide, 1980).

Toxicity to Other Beneficial Insects

Because carbaryl acts as a broad-spectrum pesticide (EPA, 1980), a certain amount of toxicity to a wide variety of insects and other arthropods may be expected. Many insects in the order Hymenoptera (this order includes the honey bee) seem to be especially susceptible to carbaryl (Abu and Ellis, 1977; Adams and Cross, 1967; Plapp and Vinson, 1977; Stern, 1963).

Aquatic Toxicity

Concentrations of approximately 10 ppm carbaryl are lethal to three of five species of marine algae.

Toxicity of 1-Naphthol

The major microbial degradation product of carbaryl is 1-naphthol. In a laboratory study (Stewart et al., 1967), carbaryl was shown to be 30 to 300 times more toxic than 1-naphthol to crustaceans (shrimp and crabs).

Diesel Oil

Mammalian Toxicity

According to the American Petroleum Institute (1983), the major hazards to mammals from diesel oil in the environment include the adherence of oil to the fur of animals, possibly resulting in hypothermia, and sublethal effects in small mammals from contaminated forage.

Toxicity to Beneficial Insects

Based on available studies, diesel oil appears to be highly toxic to honey bees, suggesting the potential for a high degree of toxicity to other invertebrates. The use of adjuvants, such as spray oil, diesel oil, and surfactants, with insecticides causes slightly increased mortality of honey bees.

Avian Toxicity

Diesel oil is slightly toxic to birds.

Threatened, Endangered, And Candidate Species

A set of mitigating measures, developed with concurrence from the U.S. Fish and Wildlife Service that will result in no effect to nesting eagles, will be incorporated in project operations plans and implemented during treatment.

A list of candidate species, which may occur in some areas, was also provided by the U.S. Fish and Wildlife Service. No effect from treatment is anticipated for these species.

In areas planned for treatment, the project leader will coordinate with the Forest Threatened, Endangered, and Sensitive Species Coordinator, and take appropriate action to assure that threatened, endangered, or sensitive plants are protected.

Fisheries/Aquatic Ecosystem

Alternative A

No effects on fisheries resulting from water temperature increases are expected.

The No-action Alternative, having minimal adverse impacts on water quality, would have similar minimal effects on fisheries. Aquatic invertebrates would not be affected by the No-action Alternative.

Alternative B

Few toxic effects have been reported in studies of aquatic species exposed to *B.t.*

Alternative D

The impact on fisheries and aquatic systems is expected to be the same as effects from Alternatives B or C.

A buffer zone will be left adjacent to streams, lakes, wetlands, and other waterways when applying carbaryl. This buffer strip must be at least one swath wide.

Aquatic Toxicity

Fish

Diesel and jet fuels and fuel oils are moderately to highly toxic to fish (based on the toxicity categories of EPA, 1985).

The risk of adverse effects from exposure to insecticides that drift offsite, and accidents, was estimated for the representative aquatic species.

The results of the risk analysis indicate there is no significant risk of acute adverse effects to any of the representative aquatic species for typical and worst-case exposures resulting from drift.

Carbaryl degrades rapidly in water in 1 to 5 days.

Fate in Plants

The low vapor pressure of carbaryl makes it unlikely that it will volatilize from plant surfaces. The susceptibility of carbaryl to photolysis, and its low solubility, minimize the possibility of washoff from plants.

Small amounts of carbaryl may be absorbed by roots and foliage and distributed into plants (EPA, 1984).

Carbaryl is nontoxic to most plants when applied at label rates (Amer, 1965). Carbaryl has been found to injure Boston ivy, Virginia creeper, and maidenhair fern (Union Carbide, 1982), as well as pears, watermelons, and some types of apples (Thomson, 1979). Minor stunting of conifer seedlings has also been observed (Sutherland et al., 1977), and retarded germination of grasses may result from excess dosages of carbaryl (Thomson, 1979).

Biological Uptake

Carbaryl is not subject to significant bioaccumulation in aquatic ecosystems because of its low solubility. Uptake of carbaryl in fish has been detected, with 95 percent excreted within 8 hours (Tompkins, 1966).

Invertebrates

Some aquatic insects in the orders Plecoptera (stoneflies) and Ephemeroptera (mayflies) are highly sensitive to low levels of carbaryl. Trichoptera (caddisflies) and Diptera (true flies) are also sensitive to carbaryl.

Aquatic Plants

Carbaryl was nontoxic to a species of fresh-water algae at 1.0 ppm.

Cultural Resources

Alternative A

No effect on cultural resources.

Alternatives B, C, and D

The only ground-disturbing activity to be encountered under these alternatives is the possible establishment of new heliport sites within forested areas.

Wilderness

The following objectives define management of insects and plant disease in Wildernesses (FSM 2324.1):

1. "To allow indigenous insect and plant diseases to play, as nearly as possible, their natural ecological role within wilderness.

2. To protect the scientific value of observing the effect of insects and diseases on ecosystems and identifying genetically resistant plant species.

3. To control insect and plant disease epidemics that threaten adjacent lands or resources."

The life cycle of the western spruce budworm suggests the lack of treatment in Wildernesses does not pose a threat to non-Wilderness (i.e., adjacent) lands nor threaten the resources within Wildernesses. Therefore, in the majority of instances, natural processes would be allowed to continue without control in Wildernesses

In situations where spruce budworm infestations in Wildernesses might affect adjacent non-Wilderness resources, treatment would be evaluated on a case-by-case basis.

Alternative A

Since the western spruce budworm is an indigenous component of the forest environment, any effects to forested areas during a naturally occurring budworm outbreak are, by policy, an acceptable part of the natural ecology.

Alternatives B, C, and D

Insecticide application would interfere with the natural processes which are a key part of the Wilderness resource.

Fire And Fuels

The No-action Alternative has little impact on fuel loading in areas where only scattered mortality occurs. The total fuel loading does not change significantly. Severe defoliation that results in areas of continuous mortality will experience high fuel loading. Forest fires result when this buildup of fuel is coupled with dry summers and lightning, or other sources of ignition.

Alternatives B, C, and D will reduce or eliminate the short-term potential for heavy fuel buildups.

All alternatives have cumulative effects on fuel levels by adding amounts of fuel to existing fuel loadings. The No-action Alternative has the most significant cumulative effect since mortality add significantly to existing fuel levels. The cumulative effects of Alternatives B, C, and D should not be significant when added to existing fuel loadings. Cumulative effects have an impact on suppression capabilities as well. As fuels are added to existing fuel beds, suppression difficulty increases.

Alternative A

The impact of continued defoliation on visual quality and the Forest users' experience will be greatest in the areas with severe defoliation.

The long-term effect of severe defoliation would result in the creation of a more diverse forest with tree species resistant to spruce budworm attack. This would result in a landscape less susceptible to change in color and texture from spruce budworm activity. This process of long-term change in tree species would take several decades.

The cumulative impact of the No-action Alternative will be the addition of acres of defoliation and visual change that occurs each year until the population is reduced by natural events.

There are conflicts with this alternative, and other plans and policies for the management of the visual resource. Conflicts result when landscape quality management objectives cannot be met due to severe defoliation impact.

Alternatives B, C, and D

Short-term protection of foliage by using *B.t.* or carbaryl reduces the change in color and texture that occurs on the landscape but does not eliminate it.

The long-term effect of protecting foliage would result in the maintenance of a forest with tree species susceptible to continued defoliation.

Notification of a pending spray project, instructing the public on safety precautions to take while visiting a project area, will cause concern and result in a short-term loss of recreation opportunity for those individuals electing not to visit the project vicinity.

The cumulative effect of implementing Alternatives B, C, or D will be the cumulative annual reduction of acres severely defoliated.

There are no conflicts expected between these alternatives and other plans and policies for management of the visual and recreation resource.

Human Health

A risk assessment was done to assess the risks to human health of using the chemical insecticide carbaryl and the biological control agent, *Bacillus thuringiensis (B.t.)* for controlling western spruce budworm in Region 6.

In essence, the risk assessment estimated doses people may get from applying the insecticides (worker doses) or from being near an application site (public doses), then compared those estimated doses with doses shown to cause no observed effects in tests on laboratory animals.

Structure of the Risk Assessment

The risk assessment employed three principal analytical elements: hazard analysis, exposure analysis, and risk analysis.

Hazard Analysis

The hazard analysis identified the toxic properties of *B.t.*, and of each chemical insecticide originally considered for the program, in a thorough review of available toxicological studies.

Exposure Analysis

The risk assessment analyzed a range of possible exposures--from realistic to extreme--using three types of scenarios: (l) typical application scenarios (routine-typical) to estimate worker and public doses that may reasonably be expected to occur during routine operations, (2) worst-case application scenarios (routine-worst case) to give very high dose estimates not likely to be exceeded except in the case of an accident, and (3) accident scenarios to estimate public and worker doses from exposure to spray mix or concentrate, directly or in spills into drinking water.

Insecticide Spraying Operations

The insecticides examined in the risk assessment are applied aerially, using fixed-wing or helicopter aircraft.

Risk Analysis

The risk of acute and chronic health effects was evaluated by comparing estimated doses to no-observed-effect-levels (NOEL's) in laboratory animal studies, using a calculated margin of safety (MOS). A benchmark risk value of 100 was used to assess the likelihood of effects. Risk increases as the estimated dose approaches the laboratory toxicity level; that is, as the MOS decreases.

Risk to more highly sensitive individuals, such as the aged or children who may be affected at extremely low exposure levels, was based on the likelihood of a sensitive individual being exposed.

Data Gaps and Uncertainties

There were a number of data gaps and areas of uncertainty identified in the risk assessment. In each of those areas, a conservative approach was used or a worst-case analysis was done that tended to increase the estimates of risk to err on the side of safety.

Risk Assessment Results

Hazard Profiles

This section summarizes the toxic properties of carbaryl, diesel oil, kerosene, and *Bacillus thuringiensis.*

Carbaryl

The review of 10 chronic toxicity, studies and the absence of significant tumor incidence at 400 ppm in rats and mice, has provided sufficient evidence for EPA to conclude "that carbaryl is not oncogenic in experimental animals" (EPA, 1988v).

Mutagenicity

The reproductive effects assessment group of EPA concluded that data from mutagenicity studies indicate that carbaryl does not act as a potent mutagen and can be classified as a weak mutagen (EPA, 1988v).

Diesel Oil

Based on an acute oral dose, diesel oil can be classified as a very slightly toxic compound.

Because diesel oil contains polycyclic aromatic hydrocarbons and other constituents that are known or suspected mutagens, it is considered to be a mutagen.

Kerosene

Kerosene can be classified as slightly toxic.

Reproductive/Developmental Toxicity

No data were available to determine the reproductive toxicity of kerosene.

Carcinogenicity

The carcinogenic potential of kerosene is similar to that of diesel oil.

Mutagenicity

Kerosene was nonmutagenic both with and without metabolic activation in the Ames bacterial and the mouse lymphoma assays (Conaway et al., 1982)

Bacillus Thuringiensis

Reproductive and Developmental Toxicity

The literature contains no data about the reproductive or teratogenic effects of *B.t.*

Carcinogenicity

The literature contains no data about the carcinogenic potential of *B.t.*

Quality of the Toxicity Data

The quality of the toxicity data base for carbaryl is adequate. Sufficient data exist from available studies to evaluate all toxicity endpoints.

Data on diesel oil and kerosene are not available for most toxicity endpoints. The quality of the data base for these two petroleum distillates must be considered inadequate.

Data do not exist for a number of toxicity endpoints for *Bacillus thuringiensis*. The quality of the data base for *B.t.* must also be considered inadequate.

Risk Of General Systemic And Reproductive Effects

Margins of safety (MOS's) were computed for workers and the public for routine operations (typical and worst-case exposures), and for accidents, for carbaryl, diesel oil, kerosene, the combined petroleum distillates, and for *B.t.*

Risk To The Public In Routine Operations

No systemic or reproductive effects are likely to result from the use of carbaryl or *B.t.* in spruce budworm supperession operations.

Margins of safety for systemic effects projected under this routine worst-case scenario are greater than 100 for carbaryl and kerosene. MOS's for diesel oil and the combined petroleum distillates are greater than 100 except for dermal and inhalation exposure to drift. These results indicate there is some slight risk of effects from diesel oil/petroleum distillate drift exposure.

Margins of Safety for Special Case Analyses

Margins of safety for persons drinking contaminated water from runoff in The Dalles Watershed were calculated. None of the MOS's are lower than 100 for any of the feeder streams. MOS's are greater than 1,000 for the reservoir itself, so there is little risk from runoff when large areas of a watershed are sprayed, even when rain occurs immediately after spraying.

Margins of safety for persons eating crops irrigated with contaminated water were calculated. MOS's are

all greater than 100, indicating very low risk from this potential route of exposure.

Risk to the Public in Accidents

The extent of effects would depend upon an individual's duration of exposure and any precautionary measures that were taken. For example, if people gathered a bushel of berries from a spray area, did not wash them but froze them, and then ate them every day for a month, they might experience ill effects such as nausea and dizziness. However, if people bathed after being in the forest or washed food items before eating them, the doses would drop (and thus substantially increase the margins of safety).

Risk To Workers From Routine Operations

Risk to Workers From Routine-Typical Exposures

Unprotected workers who routinely apply carbaryl may experience some toxic effects from the kerosene-diesel oil mixture.

Protective clothing can reduce worker exposures by 27 to 99 percent. Research has shown that such protective clothing can substantially reduce worker exposure. During insecticide applications to orchards, mixers reduced their exposure by 35 percent and sprayers reduced their exposure by 49 percent by wearing coveralls (Davies et al., 1982).

Workers who spill 500 milliliters (about half a quart) of insecticide concentrate or spray mix on their skin may experience acute toxic effects, if they do not wash the chemical off. For carbaryl in particular, this represents a clear risk of severe toxic effects if the chemical is not washed off.

Workers are not likely to be affected by carbaryl or kerosene if they are directly sprayed, but they may be affected by diesel oil and the combined petroleum distillates in the mixture.

Cancer Risks to the Public

Results for carbaryl, diesel oil, kerosene, and petroleum distillates indicate that no member of the public is at a greater than 8.5 in 100 million risk of cancer from routine exposures.

Cancer Risk to Workers

Workers are not at cancer risk greater than 1 in 1 million for any task or chemical. Cancer risks for worker accidents also do not exceed 1 in 1 million for any chemical.

Risk Of Effects From *B.t.* Contaminants (Bioburden)

Humans exposed to *B.t.* in spruce budworm suppression operations may be at some low level of risk from eye or skin irritation or infection, but are not at risk of any systemic effects from *B.t.*

Risk Of Heritable Mutations

No human studies are available that associate the insecticides considered with heritable mutations. Furthermore, no risk assessments that quantify the probability of mutations from the insecticides are available in the literature or from EPA.

Carbaryl was nonmutagenic in the majority of assays conducted and were nononcogenic in all of the carcinogenicity tests performed; therefore, it can be assumed that its mutagenic risk is slight to negligible. Kerosene and diesel oil both are considered to be possibly mutagenic.

Other Possible Effects Of The Insecticides

Factors Affecting the Sensitivity of Individuals

Factors that may affect individual susceptibility to toxic substances include diet, age, heredity, preexisting diseases, and life style (Calabrese, 1978).

Genetic factors also are known in some cases to be important determinants of susceptibillity to toxic environmental agents (Calabrese, 1984).

Persons with other types of preexisting medical conditions also may be at increased risk of toxic effects.

A series of dermal sensitization studies showed no evidence that *B.t.* could induce allergic hypersensitivity (Fisher and Rosner, 1959 as cited in Sassaman, 1987).

Cumulative Effects

No individual member of the public is likely to receive repeated exposures to any of the insecticides

because of the remoteness of most treatment units, the widely spaced timing of repeated treatments, and the use of a variety of insecticides for different purposes.

Summary Of Human Health Effects Of The Alternatives

Alternative A

This alternative should have no effect on human health because no chemical insecticides or biological controls are to be used.

Alternative B

This alternative presents the lowest risk of the alternatives apart from the No-action Alternative.

Alternative C

Carbaryl poses a human health risk only in the case of accidents. The petroleum distillates, kerosene and diesel oil, associated with carbaryl application do present a risk under routine worst case conditions and in accidents. The petroleum distillates present a degree of uncertainty in

the risk evaluation because of lack of data on their toxicity.

Alternative D

Human health risks of this alternative would be intermediate between Alternatives B and C. Risks would be reduced to the extent that *B.t.* is used instead of carbaryl.

Mitigating Measures

For any project that is implemented, a public information plan will be developed to ensure that timely notification is given about when and where spray operations will take place.

Economic Efficiency And Local Impacts

Alternatives will also result in both short- and long-term local economic impacts. These are typically measured by changes in income, earnings, employment, output, and other economic and financial conditions.

Alternative A

Under the No-action Alternative, a long-term reduction in the future supply of fiber is projected.

Alternatives B, C, and D

To the extent funding is available, investment in direct suppression with *B.t.* or carbaryl would be made in areas exhibiting the greatest net financial and intangible benefits.

Social Factors

The effects of both alternatives on consumers, civil rights, minority groups, and women are estimated to be minor. Generally, these effects are related to the supply of wood fiber and the resulting cost of wood products. Primary and secondary employment associated with the manufacture of wood products is also a consideration.

Incomplete Or Unavailable Information

Uncertain Data and Estimates

Data and information collected for the various analyses in the EIS, as well as the resulting estimates of effect and conclusions, vary in precision and accuracy. Some are based on censuses and many mutually-confirming studies. Others are based on samples and a few studies; some are estimates by professional specialists drawing on extensive experience with individual resource disciplines. The standard for determining the depth of analysis is that analysis be sufficient to provide "a clear basis for choice among options"--in this case, a choice among the four alternatives considered in this EIS.

Reasonably Foreseeable Significant Adverse Effects

An open public process was used in preparing this EIS to identify significant issues. Issues identified are issues because of the potential for reasonably foreseeable significant adverse impacts on the human environment. The potential impacts are in the areas of human health, social and economic effects, and environmental effects.

Economic Impacts

Western spruce budworm management will affect the Forest Service's ability to provide goods and services. Predicted decline in forest growth as a result of budworm defoliation can be reasonably estimated.

Environmental Impacts

By using appropriate assumptions and professional judgment, effects of actions can be reasonably estimated with confidence. While no estimate of effects for a given alternative is absolutely correct, the relative effects--compared to other alternatives--is correct. There is sufficient information with regard to environmental effects to provide a clear basis for choice among options.

Incomplete and Unavailable Information

Information is incomplete or unavailable in the following areas:

- Field studies on exposure to workers.
- Information on public exposure.
- Field data on residue levels in plants and animals.
- Mutagenicity study data for carbaryl (DNA damage)
- Toxicity information on the cumulative effects from exposure to forestry-use insecticides, other pesticides, and/or other chemicals.
- Toxicity, infectivity, and exposure information for B.t. to supplement the data from the history of its use.

Statement of Relevance

The relative human health effects of insecticies can be compared among alternatives. Comparisons were made for accidents from spills in a variety of environmental settings. The uncertainty for which there is incomplete and unavailable information is for the actual human health risks from insecticides.

Unavoidable Adverse Effects

Implementation of any alternative would result in some adverse environmental effects that cannot be avoided. Standards and guidelines and mitigating measures developed in the EIS are intended to keep the extent and duration of these effects within acceptable levels, but adverse effects cannot be completely eliminated.

Because the EIS examines alternative methods for managing western spruce budworm outbreaks the focus is on how the different methods could affect the environment. From this perspective, there are three areas of potentially significant adverse effects:

- human health risks;
- environmental effects on fish, wildlife, domestic stock and nontarget insects.
- economic effects.

Chapter 1: Purpose and Need

Eggs

CHAPTER I. PURPOSE AND NEED FOR ACTION

Introduction

Large portions of the National Forests in Oregon and Washington are actively managed to produce timber, recreational opportunities, forage, water, and wildlife habitat. An integral part of management is protection of resources from destructive agents, including insects, disease, fire (natural or human-caused), flood, and drought.

Insects play various roles in the ecological systems of National Forests, creating both beneficial and detrimental effects on Forest resources. Insects are an important part of the ecological system and understanding their role is key to effective management of forests.

Current Situation

Various plant communities on the east side of the Cascade Range have been experiencing an ongoing infestation of western spruce budworm. Douglas-fir, western larch, grand fir , white fir, Englemann spruce, and subalpine fir are the primary source of food for western spruce budworm. The spruce budworm consumes and destroys much of the new foliage on these trees. The result is vast areas of brown defoliated trees, many of which could eventually die. The defoliation associated with this infestation has killed a large number of trees. Although western spruce budworm is always present in the forest, a high level of budworm activity has been reached and the associated damage has caused considerable concern to landowners, recreationists, and other National Forest users. Effects of defoliation on humans:

- Current loss of economic value of forests not reaching maturity and producing harvestable timber.
- Decline in aesthetic values for sightseeing and recreation in the forest.
- Decrease in future supply of goods and services in affected areas.

The current western spruce budworm outbreak now encompasses approximately 7 million acres. The intensity of the outbreak is declining in some areas, while it is increasing in other areas. Efforts to control the current infestation could have important consequences on the social, biological and physical environment.

Chapter 2 of this Environmental Impact Statement (EIS) describes four alternatives for managing the current western spruce budworm infestation on National Forest land in eastern Oregon and Washington. These alternatives are: A. No action, B. Spray with *B.t.* only (natural biological material), C. Spray with Carbaryl only (chemical insecticide), and D. Spray with *B.t.* and/or Carbaryl.

Description Of The Insect

The western spruce budworm (*Choristoneura occidentalis* Freeman) is a native insect species. It is the most widely distributed and potentially destructive insect of coniferous forests in western North America. The western spruce budworm is one of nearly a dozen species, subspecies, or forms of a spruce budworm complex found throughout the western, north-central, and northeastern United States, and in several western and maritime Canadian provinces. The genus is also represented in Europe.

In Oregon and Washington, the budworm completes one cycle of development from egg to adult within 12 months. Following flight in late July and August, the adult moths lay eggs that soon develop into tiny larvae which overwinter in an inactive state in sheltered places, under bark scales, and in or among lichens on tree boles or limbs. In early May to late June, larvae emerge and begin their active feeding stage. As rapidly growing larvae, spruce budworms molt (shed their skin) a total of five times. The six intervening stages are called instars. After about 30 to 40 days, larvae develop into pupae. The moths emerge from the pupae after about 10 days to begin the cycle again.

Within its range, the budworm infests forests in a variety of ecological situations: in pure and mixed

Figure I - I

National Forests of the Pacific Northwest Region

stands on both poor and good sites, over wide topographic, physiographic, climatic, geographic, and elevational gradients, and in a variety of habitats. In Oregon and Washington, the vegetation zones affected are the Douglas-fir and true fir zones (Franklin and Dyrness, 1973) and include the ponderosa pine/Douglas-fir co-climax, mixed conifer, white fir, and subalpine fir plant communities (Hall, 1973). The budworm feeds on all age classes of host tree species.

The most common host tree species are Douglas-fir, grand fir, white fir. subalpine fir, Engelmann spruce, and western larch. Occasional host species include lodgepole pine and ponderosa pine. On most host tree species, western spruce budworm larvae feed as typical defoliators. Though preferring succulent new foliage, they also feed on older foliage when new foliage is in short supply or is not available. By the time larvae reach maturity in early to mid-July, they often have consumed or destroyed much of the new foliage on host trees.

Western spruce budworm larvae also feed on the cones and seeds of several species of host trees, particularly Douglas-fir (Dewey, 1970) and western larch (Fellin and Shearar, 1968).

Budworm populations are usually regulated by several natural factors such as parasites, predators, and adverse weather, especially when populations are low (Dewey, 1974). Starvation can also be an important mortality factor in regulating populations during prolonged outbreaks. More than 40 species of parasites are known which attack the budworm larval stage, but none has been found to have much effect on high budworm populations during an outbreak (Torgersen et al., 1984).

Studies in other areas indicate that weather may be the natural factor with the most dramatic effect on budworm populations. Small larvae, hatching from eggs or disbursing from their overwintering sites, may be blown from the host tree to the forest floor where they are often eaten by predators or die from exposure to sunlight or starvation. Cool summer weather retards feeding and development, increasing the time larvae are vulnerable to predators and parasites. Occasionally, larvae have not emerged from eggs before the first freezing temperatures in late summer and early fall. It has been suggested that collapse of populations may also occur because of exceptionally warm weather in the autumn. This results in the larvae remaining active rather than locating places where each can overwinter. Under these conditions, active larvae deplete their reserves of nutrients obtained from the egg. Without these reserves, the majority of the larvae would starve during the winter and early spring before they could do serious damage to their host plants. Conversely, it is also believed that favorable weather, such as late onset of fall freezing and warm spring and summer conditions, is a major contributor to population increases.

In some forested areas, the individual or combined effects of natural factors is probably responsible for the decline, termination, or pattern of western spruce budworm outbreaks. However, the ineffectiveness or absence of natural mortality factors is often responsible for population resurgences. Because the ecosystems of Oregon and Washington provide a variety of ideal habitats for the budworm, the combined effect of natural agents does not prevent or reduce population resurgences when climatic and forest stand conditions are favorable.

Scope Of The Decision

The scope of the decision for the EIS is limited to dealing with the question of what should be the strategy for managing the current outbreak. Scoping to identify public issues revealed that one of the major issues is the question of what can be done in the long term to reduce spruce budworm outbreaks. Long-term management through silvicultural treatments and prescribed fire is seen as a lasting solution to management of spruce budworm outbreaks. The Forest Service agrees that the best long-term strategy for management of spruce budworm populations is through silvicultural treatment and prescribed fire.

When considering long-term management strategies for dealing with the future health of the forest, we find that spruce budworm is only one of many insects and diseases of concern. Complex interactions of forest insects and diseases exist in all forest plant communities. For example, management strategy for one insect or disease may increase or decrease the effects of other insects and disease.

The Forest Service does not presently have the operational capability to make long-term strategic decisions for management of the complex of insects and disease. The Forest Service commitment is to have this capability within 5 years. The Region will utilize this capability on each National Forest to determine long-term management strategies.

Decision Needed

The decision needed in this EIS is how to manage the current spruce budworm outbreak, and if so, what methods to use. During the investigation of possible

actions and their predictable environmental effects, four alternatives were developed for managing the current outbreak of the western spruce budworm on lands administered by USDA Forest Service, Bureau of Land Management, Bureau of Indian Affairs, and State and private lands in Oregon and Washington. This EIS displays the environmental impacts and management implications of these four alternatives.

This EIS is presented in draft form to provide an opportunity for public review and comment. After carefully considering comments on this draft from scientists, Government agencies, and the public, a Final Environmental Impact Statement (FEIS) will be prepared and issued, along with a Record of Decision. The Regional Forester will use the FEIS as a basis for indicating the Regional Forester's preferred alternative.

Summary Of Prior Events

The western spruce budworm, *(Choristoneura occidentalis* Freeman), is the most widely distributed defoliator of coniferous forests in western North America (Fellin and Dewey, 1982). The destructive feeding period is during the caterpillar (larval) stage of the insect; the adult is a small orange-brown mottled moth. Native to most fir stands, the insect's population levels are usually held in check by the interaction of parasites, predators, timber stand conditions, and weather. Periodically, the complex of natural controls no longer limits growth of budworm numbers and an outbreak occurs.

At epidemic levels, budworms may defoliate entire timber stands, feeding primarily upon new needle growth and affecting mostly Douglas-fir, grand fir, and white fir which are the preferred host species. Outbreaks typically last from 6 to 10 years, resulting in five types of damage to host trees: growth loss, top-kill, deformity, reduced seed production, and mortality.

A major western spruce budworm outbreak, encompassing 10 National Forests, BLM, BIA, and adjacent State and privately owned lands, currently exists in the Pacific Northwest Region. Budworm defoliation was first detected during an aerial survey in 1980 when 6,000 acres were mapped in the Mill Creek Drainage near Cove, Oregon. By late summer of 1981, the number of defoliated acres had risen to 300,000. During the summer of 1982, an environmental analysis of the situation led to an insecticide spray project, using carbaryl and acephate on 178,549 acres in the Umatilla and Malheur National Forests.

In August 1982, an aerial detection survey showed the outbreak then covered 1.5 million defoliated acres, which was a substantial increase. Based on another analysis, it was decided to conduct a second control project, this time aerially treating 524,561 acres with chemical insecticides on the same two Forests during the summer of 1983.

The defoliated acreage increased to 2.4 million in 1983, prompting another analysis. A small 850-acre field test of the biological insecticide *Bacillus thuringiensis (B.t.)* was conducted on the Ochoco National Forest. In 1984, defoliation covered 2.9 million acres, prompting another analysis of the situation. Treatment carried out in 1985 was an operational evaluation of several formulations of *B.t.* on about 40,000 acres. Defoliated acres increased to 3.6 million in 1985. In 1985 and 1986, an analysis was again conducted, this time considering only the alternatives of no action and treatment with *B.t.* No treatment was done in 1986 due to lack of suppression funds. The outbreak increased to 6 million acres in 1987. In 1987, 135,000 acres were treated on the Wenatchee and Malheur National Forests. In 1988, 600,000 acres were treated on the Mt. Hood National Forest, Umatilla National Forest, Warm Springs Indian Reservation, and Umatilla Indian Reservation.

In 1988 the need to take a broader look at the outbreak was recognized. The commitment has been make to develop the operational capability needed to prepare management strategies for the complex of insects and disease.

History Of Western Spruce Budworm Control In Oregon And Washington

Western spruce budworm was first recorded in the Pacific Northwest Region in 1914, when specimens were reared from Douglas-fir at Ashland, Oregon (Lindsten et al., 1949). Subsequently, budworm defoliation was noted in limited areas near Northport, Washington in 1928, in central Oregon near Mitchell in 1931, and in the Warner Mountains southeast of Lakeview, Oregon, in 1932, 1941, and 1942 (Lindsten et al., 1949; and Carolin, 1965). All of these outbreaks were small and subsided without causing appreciable damage to timber stands.

In 1943, budworm defoliation was discovered in the Methow Valley on the Okanogan National Forest in north-central Washington. This infestation eventually developed into the first major recorded western spruce budworm outbreak in the Pacific Northwest Region.

An estimated 200,000 acres were defoliated before the infestation collapsed from natural causes in 1948. In 1944, an infestation developed on the Umatilla National Forest in northeastern Oregon that eventually involved the entire fir-host type throughout the Blue Mountains.

A summary of western spruce budworm control projects conducted in Oregon and Washington from 1949 through 1988 is shown in Table I-I. Dolph (1980) provides greater detail about both budworm activity and the control projects that occurred through 1979.

Since 1970, budworm activity has been concentrated in three areas of the region: the east slope of the Washington Cascade Range, the east slope of the Oregon Cascade Range, and the Blue Mountains of northeastern Oregon. Table I-II shows the progression of an outbreak on the east slope of the Washington Cascades which started in the early 1970's. Insecticides were applied in 1976 and 1977, and the population declined to endemic levels by the early 1980's. Populations have been increasing since that time. South of the 1970's outbreak area, budworm populations have caused considerable defoliation in the Rimrock Lake area on the Wenatchee National Forest. This area was treated with insecticide in 1987.

A relatively small outbreak occurred on the east slope of the Oregon Cascades on the Warm Springs Indian Reservation in the mid to late 1970's. Insecticides were applied in 1976, 1977, and 1979. The population subsequently collapsed in 1979. Populations in this area have again increased.

A major budworm outbreak in the Blue Mountains of Oregon began in 1980 and is continuing. Insecticides were applied in 1982, 1983, 1985, 1987, and 1988 to portions of the outbreak area. During the 1985 aerial survey, defoliation was again detected over most of the area treated in 1982 and 1983.

A number of insecticides have been used since 1976. Recent evaluation has focused on the use of *Bacillus thuringiensis* (*B.t.*), a microbial insecticide (Beckwith et al., 1984; and Ragenovich, 1985).

Although the current outbreak was first observed in northeastern Oregon in 1980, western spruce budworm infestations have subsequently appeared in other parts of Oregon and Washington. Budworm defoliation in the current outbreak was first detected from the air on the east slope of the Cascade Mountain Range in Oregon in 1983. At that time, the infestation covered about 66,000 acres on the Mt. Hood National Forest, adjacent State and private lands, and the Warm Springs Indian Reservation. Defoliated acreage increased to 160,000 in 1984, including some acreage on the Deschutes National Forest. The apparent defoliation had increased to about 640,000 acres in 1985, and to about 910,000 acres in 1986. This is the first outbreak of comparable size on the eastern slope of the Oregon Cascade Range since the late 1940's. A smaller outbreak on the Warm Springs Indian Reservation, which began in 1974, was treated with a 34,000-acre insecticide spray project in 1979.

On the east side of the Cascade Range in Washington, western spruce budworm defoliation was first detected in 1970 on the Okanogan and Wenatchee National Forests. This outbreak increased to over 1 million acres in 1976 and 1977. Insecticide treatment was carried out in 1976 (358,000 acres) and 1977 (356,000 acres). The remaining untreated populations seemed to diminish significantly in 1978. Defoliation was again detectable in the original outbreak area by 1983. Different areas of defoliation began appearing in 1978 on and adjacent to the Tonasket Ranger District on the Okanogan National Forest. Defoliation has been detected to varying degrees since that time with 448,000 acres detected in 1986, including some previously treated areas.

On the Naches Ranger District, Wenatchee National Forest, 12,000 acres of budworm defoliation were mapped in 1984, 134,000 acres in 1985, and 80,610 acres in 1986. This is the first western spruce budworm defoliation to be reported in the area.

The 1987 summer aerial detection survey, and subsequent egg mass and defoliation survey, revealed the epidemic budworm populations had not collapsed. The defoliated area then covered nearly 6 million acres in Oregon and Washington combined. This might seem to imply that the insect populations spread widely from a common geographic source. Instead, endemic populations in various locations expanded simultaneously in response to favorable conditions, primarily related to weather. The infestation is located on lands of diverse ownership, having significant potential impacts on management objectives and practices of many private and public land managers.

In 1988, a major set of suppression and developmental projects was conducted in Oregon to deal with the current outbreak.

Operational units sprayed with *B.t.* on the Mt. Hood National Forest had the following results: The Dalles, 2.40$\pm$.36 larvae/45 centimeter branch tip on an area of 116,000 acres; Barlow, 0.56$\pm$.07 larvae/tip on an area of 140,000 acres; and Warm Springs, 0.57 larvae/tip on an area of 186,000 acres. The Dalles units did not meet acceptable control limits. Spray assessment indicated there were considerable areas that had poor application. Added to this were very high populations of budworm in the unit.

Operational units on the Tollgate project on the Umatilla National Forest had the following results: 0.55±.008 larvae/tip and 0.68±.02 larvae/tip over approximately 107,000 acres, and 1.42±.15 larvae/45 centimeter branch tip over approximately 2,000 acres.

Projects conducted by Longview Fiber (a wood products company) and Hood River County used both carbaryl and *B.t.* Over an area of 33,000 acres, carbaryl reduced populations below 1 larvae/45 centimeter branch tip on 14 out of 15 spray blocks. *B.t.* gave variable results over 6,700 acres with two out of five blocks having an average of less than 1 larvae/tip. The difference in results may be due to differences in spray deposit. The average deposit on carbaryl cards was 25 drops/square centimeter, whereas *B.t.* averaged 14 drops.

In a pilot project conducted near Meacham, Oregon, to determine the feasibility of using undiluted formulations of *B.t.* at 43 oz.(16 BIU)/acre, the following results were obtained: *B.t.* formulation Dipel 6AF, 2.17 larvae/45 centimeter branch tip, 87.8 percent population reduction; *B.t.* formulation Thuricide 48LV, 1.03 larvae/tip, 94.7 percent population reduction; and the control 7.83 larvae/tip, 54.7 percent population reduction. These are preliminary results, however it appears that only the Thuricide 48LV may have met the criteria of reducing the population to less than 1 larvae per tip.

A special project was conducted on the Mt. Hood National Forest to determine the handling and application characteristics of two formulations of *B.t.*; Dipel 6L, applied undiluted at 42.7 oz. (16 BIU)/acre and Thuricide 32LV, applied undiluted at 64 oz. (16 BIU)/acre. Preliminary results indicate that both formulations reduced populations of budworm below the 1 larvae/45 centimeter branch tip threshold. Thuricide 32LV reduced populations to 0.28±.08 larvae/tip. Dipel 6L reduced populations to 0.90 larvae/tip.

Public Involvement

Meetings have been conducted with a variety of interested agencies, interest groups, industry, and interested individuals.

A brochure requesting comments and concerns was mailed to approximately 2,000 groups and individuals to help identify issues, and concerns. Press releases were mailed to the media in the affected areas.

A total of 206 responses were received through distribution of the scoping brochure and included approximately 550 substantive comments. These comments were analyzed to identify issues, alternatives, and analysis criteria needed to evaluate the possible alternatives.

Major Issues And Concerns

Beginning in 1981, and continuing through successive years of environmental assessments (EAs), numerous concerns have been expressed about the current western spruce budworm outbreak, and associated spray programs, in the Pacific Northwest. The issues and concerns developed during the 1984 northeastern Oregon analysis were used as a starting point to build upon during 1985. The public involvement steps used for scoping in 1986 included meetings and written inquiries. In 1986, 1987, and 1988, some additional public meetings were held by individual Forests. In addition, interested parties were solicited in writing for additional issues and concerns that were not addressed in prior EAs. Public meetings, personal consultations, news clippings, and correspondence resulted in identification of public issues, and management concerns. These items reflected the views of concerned individuals, forest-based industries, landowners of various-sized forest holdings, forest resources user groups, conservation and environmental groups, Indian tribes, and representatives of local, State, and Federal agencies and governments.

Based on responses to mailings conducted as part of this EIS, and concerns identified in past EAs, eight major public issues were identified in the scoping process. They include silviculture; water quality and quantity; fish, wildlife, and domestic animals; economics; human health; effectiveness of treatment methods; timeliness of treatments; and fuels and fire. A discussion of these issues follows:

Silviculture

The effects on timber production of both treated and untreated budworm outbreaks are quite complex. Long-term management of timber stands through silviculture treatments as a means to end the epidemic is an issue. Therefore, budworm suppression programs would only minimize short-term growth losses. Concern has been expressed that untreated budworm infestations may negate efforts to increase timber growth rates through intensive timber management, and that long-term yields and harvests may be reduced from present levels. It has been suggested that direct budworm control measures will be needed until timber stands contain healthy mixed-species, less vulnerable to budworm infestation. There is concern that our past silvicultural practices

have led to species composition and stand conditions that are susceptible to spruce budworm.

Water Quality and Quantity

Two broad areas of concern are included in this issue; possible hydrologic changes that might occur in watersheds if the budworm outbreak is left unchecked, and possible contamination of water quality from the use of insecticides. Some members of the public have asserted that widespread defoliation may result in variations to timing and quantity of water yield in heavily affected watersheds; increased flows could result in streambank cutting and greater sediment loads. Hydrologic changes could also affect unstable slopes and cause increased mass failure activity.

A number of people are concerned about monitoring activities. They believe that monitoring should be adequate to assess the short- and long-term effects of treatment on water quality and riparian zones.

Most concern about possible water quality centers on the use or accidental spills of chemical insecticides. The nature of ingredients in *B.t.* formulations and the use of spreader/sticker agents in this biological insecticide are also a concern. Individuals have expressed concern about possible adverse effects to aquatic life and irrigation water. However, the central issue involves direct human use of water that may contain insecticides. Protection of water quality in Oregon and Washington municipal watersheds, such as those of The Dalles, Dufur, and Walla Walla, is of great concern.

Fish, Wildlife, and Domestic Animals

People are concerned that fish, wildlife and domestic animals could be adversely affected the budworm infestation or by insecticide control programs.

Big game species may be affected if budworm defoliation changes the quantity and/or quality of coniferous cover used for thermal, hiding, and escape cover. Some people expressed concern that ungulates (deer, elk) may be adversely affected by ingesting insecticides on forage. Since spraying of insecticides usually occurs about the same time as spring birthing, some people expressed concern about the effects (increased desertion of young, vulnerability to predation) of increased human disturbance on this critical biological activity. Bighorn sheep deserting their young as a result of human disturbance was mentioned in particular.

Concerns were also expressed about possible adverse effects on vertebrate species (birds, small rodents, and squirrels) that consume budworms and other insects if spray projects are initiated. While insectivorous bird species were mentioned most often in this regard, concern was also expressed for several species of raptors, geese, flying squirrels, bats, toads, lizards, salamanders, and snakes. Other concerns was expressed for federally classified threatened or endangered species, and that a reduction in food supply for several species could cause relocation, and reduction in nestling survival.

Concerns were expressed about possible adverse effects of spraying insecticides on natural predators of the budworm, pollinator species, and livestock, upsetting the natural balance and resulting in a yearly need for repeat spraying.

Many people expressed a strong desire for monitoring programs to better assess the direct and secondary effects of control programs on nontarget species. These data would then provide a better source of information upon which to base future budworm control decisions.

The same concerns described for terrestrial wildlife were also expressed for aquatic wildlife. The greatest concern involved possible adverse effects to fish (native and anadromous), either through direct exposure to insecticides or through reductions of aquatic insect food supplies. The safety of human consumption of fish from oversprayed streams was also a concern. Many people believe stream buffers were the only measures used to protect aquatic resources. The need for monitoring for direct and secondary effects was emphasized.

Economics

Nearly all members of the public want to know if their money is being spent wisely. The benefits and costs of alternatives being considered for dealing with the budworm outbreak should be displayed and compared. Opinions have been expressed regarding factors that should enter into the economic efficiency analysis and the appropriateness of assumptions used in past analyses. Benefits and costs associated with the following factors have been suggested for consideration: timber growth loss, effectiveness of *B.t.* compared to carbaryl, risk of budworm population resurgence and reinvasion of treated areas, the risk of future outbreaks in the area, and reduced recreation use.

Concerns have been expressed about the economic effects to private landowners from a possible "no action" decision on adjacent public land, particularly those areas with management strategies such as Wilderness.

Concern has been expressed regarding possible reductions in National Forest timber harvest levels

because of the budworm outbreak and subsequent effects on employment and community stability.

Human Health

Most people who have expressed concern with budworm control projects want an understanding of possible hazards associated with the use of the insecticides being considered. The potential for long-term, short-term, and cumulative effects on human health is a concern. Possible effects on pregnant women, children, older people, and chemically sensitive people have been mentioned.

Most people believe high priority should be placed on preventing accidents and spills, and that if mishaps occur, the response should be swift and appropriate. Timely public notification should be given so people can avoid treatment areas. Emphasis on safety should be given throughout contract preparation, contract administration, and all operational aspects of a spray project.

Many of the people showing an interest in budworm control programs expressed a preference for continued biological rather than chemical insecticides. There are concerns about cumulative health risks from existing chemical use in the environment, and that additional chemical pesticide applications will add to human health hazards.

Effectiveness of Treatment Methods

A concern was expressed about the effectiveness of available treatment methods in managing the western spruce budworm infestation. The effectiveness of insecticides is dependent upon application techniques and proper timing. The efficacy of a biological insecticide is more dependent upon weather conditions than chemical insecticides. Unlike chemical insecticides, biological insecticides must be ingested by western spruce budworm larvae to be effective. Treating too early can result in many individual larvae escaping exposure to *B.t.* because they are not feeding on foliage that is exposed to the spray of *B.t.* the effectiveness can be diminished by exposure to sunlight before being ingested by larvae. Treatment administered too late might result in avoidance of *B.t.* by larvae that have advanced into the late sixth instar and have ceased feeding prior to pupation.

Timeliness of Treatments

Throughout its range, detectable populations of the western spruce budworm appear to persist indefinitely in stands that contain a substantial proportion of suitable hosts. Concern was expressed that immediate suppression action could limit the spread of an infestation and prevent a widespread outbreak.

Fuels and Fire

Many years of effective fire suppression efforts have caused accumulations of needle litter, dead limbs, and dead trees which can lead to high intensity wildfires. Outbreaks of mountain pine beetle, western spruce budworm, and Douglas-fir tussock moth have contributed and are presently increasing fuel loading. However, recent insect epidemics have increased the rate of accumulation. The greatest hazard at present comes from four conditions:

1) areas of dead and down woody debris created from insect mortality;

2) stands at higher elevations where there is historically a high rate of ignition by lightning;

3) precommercial thinning slash;

4) areas with a high rate of spread fuels, such as logging slash.

Planning Questions:

Analysis of public responses shows that many of the issues and concerns were interrelated to some degree. Those most closely interrelated have been grouped into eight planning questions:

1) What are the economic implications of potential alternatives?

The potential losses in timber growth and yield due to foliage loss are of concern. Visual resources are also affected by spruce budworm as foliage becomes red or trees die. This may have an effect on the local economies of small communities dependent, in part, upon recreation income. Spraying projects bring dollars to the local economy by creating employment opportunities for local citizens and purchasing goods and services.

2) How effective are available treatment methods in reducing the insect population? (Efficacy)

The efficacy of *B.t.* and other pesticides is directly related to the method of application, weather, and timing. Quality *B.t.* applications, as well as quality carbaryl applications, are likely to suppress budworm populations below an average of 1 larva per branch tip. Is one method of control substantially more effective?

3) What are the effects of each alternative on fish, wildlife, and domestic animals?

Concerns that increased human disturbance associated with control projects upon deer and elk during fawning and calving have been raised. Some people

feel that fawns and calves would be more vulnerable to predation because of increased chances of desertion by the mothers. Bald eagle nesting territories occur within infested forests. There are concerns about the health effects on wildlife resulting from use of *B.t.* or carbaryl.

4) What is the effect of budworm treatment or nontreatment on scenic values and recreation use?

Timber stands affected by the current spruce budworm outbreak will suffer various types and degrees of damage to visual quality of forest landscapes. Treatment would avert most of the future predicted loss due to the current outbreak.

5) What is the effect of budworm treatment or nontreatment on the potential for wildfire?

As needles, branches and entire trees drop to the forest floor, fuel loading increases. Due to the current outbreak, what is the likelihood and potential impact of an uncontrolled fire event under the various management options?

6) What are the hydrologic effects of treatment/nontreatment?

Concerns have been raised regarding the effects of the western spruce budworm infestation upon water quality and quantity. Some feel defoliation and tree mortality influence snowpack levels, seasonal snowmelt, stream temperatures, turbidity, overland flows and sediment associated with salvage.

7) What is the timeliness of treatment for this and future outbreak cycles?

Concerns have been raised about the time lapse between the discovery of the outbreak and the start of treatment. What is the most effective timing of treatment? Can early treatment stop widespread infestation?

8) What are the effects on human health associated with treatment using insecticides?

It is recognized that some segments of the public have concerns about pesticide use. It is perceived that these insecticides either pose an immediate hazard to human health, or have the capacity to cause health problems in the future.

USDA Forest Service Management Objectives

Management direction provided through laws, regulations, and policy, is detailed in a number of places. The following references contain material applicable to alternatives being considered in this analysis: (These references are available at the USDA Forest Service, Pacific Northwest Regional Office in Portland Oregon).

1. Laws Regulations And Policies

A. Preservation of Wilderness Values- Wilderness, Primitive Areas, and Wilderness Study Areas. Where a choice must be made between Wilderness values and any other activity, preserving the Wilderness resource is the overriding value. Economy, convenience, commercial value, and comfort are not standards of management or use of Wilderness. Because uses and values on each area vary, management and administration must be tailored to each area. Even so, all Wildernesses are part of one National Wilderness Preservation System and their management must be consistent with the Wilderness Act and their establishing legislation. This policy states that insect or disease outbreaks will not be artificially controlled unless it is necessary to protect resources outside the Wilderness. Insect or disease suppression projects in National Forest Wildernesses shall be based on factors set forth in FSM 3400/2320 and be approved by the Chief of the Forest Service.

B. Oregon and Washington State Forest Practices Act. The Oregon Forest Practices Act provides a set of rules establishing minimum standards which encourage and enhance the growing and harvesting of trees on state, federal and private lands. At the same time, the Act considers and protects other environmental resources - air, water, soil, and wildlife.

A key element in the Washington Forest Practices Act is the emphasis on flexibility and site-specific prescriptions. An interagency approach toward forest practices will be emphasized to ensure that impacts to soils, water quality, and habitat are better assessed.

Any project that may be implemented in Oregon and Washington must comply with the laws, rules, and regulations of these Acts. (Available at Oregon Department of Forestry offices or Washington Department of Natural Resources offices)

C. Safe and Proper Use of Pesticides. Is the authority for the registration, distribution, sale, shipment, receipt, and use of pesticides. The Forest Service may use only pesticides registered or otherwise permitted in accordance with the Federal Insecticide, Fungicide, and Rodenticide Act, as amended. (Federal Insecticide, Fungicide, and Rodenticide Act of 1972 as amended Public Law 92-516.)

D. Environmental Protection Agency Regulations. These regulations include air and water quality standards that must be met. The U.S. Environmental

Protection Agency (EPA) has responsibility, under a variety of statutes, to protect the quality of the Nation's ground water and air quality, as well as direct responsibility for regulating the availability and use of pesticide products. Since the early 1970's, the EPA's office of Pesticide Programs has been evaluating the leaching potential of new and existing pesticides and has taken regulatory action, including cancellation, on several pesticides found to have the potential to contaminate ground water. During this period, EPA has also undertaken monitoring studies and research efforts designed to help characterize the risks pesticides pose to ground water and air quality.

E. Endangered Species. Plant or animal species identified by the Secretary of Interior as endangered or threatened in accordance with the 1973 Endangered Species Act, as amended. The National Forest Management Act requires that viable populations of sensitive species be maintained to ensure they do not become threatened or endangered because of Forest Service actions. Population and/or habitat objectives need to be developed and implemented for most of the species listed by the Regional Forester.

F. Other Laws, Regulations or Policies. Any implemented project will comply with other applicable local, State, and Federal laws, regulations, or policies.

G. Land Management Plans. Treatments will comply with the direction provided in the most recently approved Land Management Plan for National Forest System lands.

2. USDA Forest Service Goals

A principle U.S. Department of Agriculture goal is to assure an adequate supply of high quality food and wood fiber and a quality environment for the American people. The USDA gives special emphasis to the development and use of efficient and environmentally acceptable integrated insect and disease management systems.

Insect outbreaks will be prevented or suppressed by methods that will restore, maintain, or enhance the quality of the environment. These objectives are attained on non-Federal lands through cooperation with State Foresters or equivalent State officials. Insects are suppressed directly on National Forest lands and in cooperation with responsible officials on other Federal lands. The Forest Service has cost-share agreements with the States of Washington and Oregon. These agreements allow the Federal Government to pay for a portion of the spruce budworm suppression costs on private lands.

Table I-I

Western Spruce Budworm Control Projects

Oregon and Washington

1949 -- 1988

	Thousands of Acres	
Year	**Oregon**	**Washington**
1949[1/]	267.0	-
1950	907.4	25.9
1951	801.6	125.0
1952	529.6	134.6
1953	369.2	-
1954	67.7	-
1955	620.9	-
1958	818.0	-
1962	-	46.2
1976[2/]	6.9	351.1
1976[3/]	-	7.7
1977[3/]	0.7	356.0
1979[3/]	34.4	-
1982[3/]	69.3	-
1982[4/]	9.2	-
1983[3/]	02.0	-
1983[5/]	12.5	-
1983[6/]	10.1	-
1985[7/]	41.0	-
1987	94.0	44.1
1988	607.5	-

[1/] DDT used in all projects 1949 through 1962 (1lb./gal. oil/A)

[2/] Malathion ULV used (13 fl. oz./A)

[3/] Sevin-4-Oil (carbaryl) used (1 lb./1/2gal. oil/A)

[4/] Orthene (acephate) used (1/2 lb./1 gal. water/A)

[5/] *B.t.* used (12 BIU/3 qts. water/A)

[6/] Zectran (mexacarbate) used (.15 lb./1 gal. oil/A)

[7/] Operational evaluation of five different *B.t.* treatments

Table I-II

Area Visibly Defoliated by Western Spruce Budworm

Oregon and Washington

1970 -- 1986

	Thousands of Acres		
Year	**NE Oregon (Blue Mtns.)**	**E Side OR Cascades**	**E Side WA Cascades**
1970	14	-	0.2
1971	28	-	18
1972	23	-	202
1973	48	-	282
1974	2	7	564
1975	8	11	513
1976	0.4	11	1,089
1977	-	19	1,176
1978	-	6	193
1979	-	29	378
1980	6	-	127
1981	313	-	30
1982	1,531	-	9
1983	2,373	66	38
1984	2,884	160	53[1/]
1985	3,600	640	420
1986	4,545	1,024.3[2/]	448.2
1987	2,875	913	466

[1/] 12,000 acres defoliated near Rimrock Lake; first time budworm defoliation ever recorded in this area.

[2/] On the west side of the Oregon Cascades (Willamette NF), 89,570 acres of visible defoliation were noted.

Chapter 2: Alternatives

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CHAPTER II. ALTERNATIVES

This chapter describes four fully developed alternatives and alternatives that were considered and eliminated from detailed study. The physical, biological, social, and economic effects are compared for each of the fully developed alternatives. This chapter draws on material from Chapter IV.

Introduction

This Environmental Impact Statement (EIS) displays four different ways of managing the western spruce budworm, including a No-action Alternative. One action alternative utilizes a biological insecticide, another uses a combination of both chemical and biological insecticide, and the third uses only chemical insecticide.

These alternatives represent the only viable methods for dealing with the current outbreak. Other options are available for preventing and reducing the occurrence of outbreaks and are discussed more fully under alternatives considered and eliminated from detailed study and in Chapter I under the topic of Scope of Decision.

There are two Forest Service-preferred alternatives identified, Alternatives B and D.

Alternatives Considered But Eliminated From Detailed Study

The Forest Service considered a range of alternatives in order to assess the reasonableness of the alternatives to be considered in detail. Those alternatives eliminated from detailed consideration, along with the rationale for their elimination, are as follows:

Suppression Using Biological Methods Other Than *B.t.*

Three types of biological control techniques have been used with some success against other insect pest species and have been suggested for use on the western spruce budworm. A brief description of each of these techniques, and reasons they were not studied in detail follows:

Sterile Male Release

This technique involves the sterilization, or partial sterilization in the laboratory, of the male of the target species through irradiation or by use of chemicals. These males are released in the field to mate with wild females that will produce either no offspring or sterile offspring. In theory, this should cause a decline in the population. This suppression technique has been tried with some success with at least one forest defoliator, the gypsy moth, but no experimentation has been done using this technique against the western spruce budworm. For this reason, it was eliminated as an alternative to be studied in detail.

Parasite or Predator Augmentation

This technique involves the rearing of parasites or predators, and release of these into the wild to attack the pest species, or the manipulation of some other factor in the environment which would cause the native parasite or predator populations to increase. Theoretically, this would help bring the population level of the pest species down to a nondamaging level. These techniques have been tried with a number of native forest defoliators, but with little success. There has been no success using these techniques against western spruce budworm; thus, they were eliminated as alternatives to be studied in detail.

Pheromone Manipulation

This technique involves the use of pheromone or insect sex attractant. This product is normally produced by female moths to attract male moths for mating. Synthetic pheromones are released into the forest, and in theory, confuse the males and make it difficult to locate and mate with females. Unmated females produce no offspring, causing a decrease in the population. Some success using this technique against Douglas-fir tussock moth has been documented, but to date, this technique has not been successful against western spruce budworm. Thus, this technique is not a realistic control option, and was eliminated as an alternative to be studied in detail.

Indirect Suppression Using Silvicultural Techniques

This alternative proposes to control the budworm epidemic with silviculture management techniques which reduce a stand's susceptibility or vulnerability to attack. The rationale for elimination of this alternative from detailed study is that implementation takes decades. Silviculture management will have little or no visible effect against the current outbreak cycle.

This long-term alternative is remedial to the widespread effect of wildfire exclusion and past harvest history (partial cutting and serial selection cutting). Over a period of many decades, the region (East-side forests) would reverse the successional trend toward a climax vegetation created or enhanced by past wildfire exclusion and partial cutting practices. A corrective management strategy would progressively revegetate the budworm-susceptible, mixed-conifer sites, creating forest types resistant to western spruce budworm. Particular timber stands would be manipulated to lessen their susceptibility to budworm infestations and vulnerability to damage.

Recent research in eastern Oregon indicates the increase in foliage produced as a result of nitrogen fertilization, may compensate the loss of foliage consumed by a very dense budworm population. This information is the result of analysis of data from experimental plots on the Malheur National Forest. Installation of experimental plots on the Umatilla and Wallowa-Whitman National Forests is scheduled for 1988. It will take 3 to 4 years for the results of these studies to be completed. If fertilization does produce favorable results, an operational program would not be realistic for 5 to 10 years. Consequently, fertilization is not a resonable option for treating the current budworm population and has been eliminated from detailed study..

Suppression Using the Chemical Insecticides Mexacarbate, Acephate, and Malathion

Mexacarbate has had very little use against western spruce budworm. It was used to treat about 10,000 acres on the Malheur National Forest in 1983. The results were inconclusive; the budworm population was not reduced below the threshold established as acceptable (Bridgwater, 1983). Because of these results and the fact the material is no longer being manufactured, entomologists no longer are interested in developing its use (Flavell et al., 1977, Stipe et al., 1977, Livingston et al., 1982).

Acephate was used in 1982-83 on the Malheur National Forest in Oregon and showed promise in small-scale field and pilot projects. Populations were reduced to a level averaging 9.1 larvae/100 buds, but treatment did not prevent significant defoliation (Hostetler, 1983).

Malathion has been inconsistent in suppressing populations of budworm in the Northwest. In 1976, it was applied to 358,000 acres in Washington and Oregon; however about 123,000 acres had to be retreated in 1977 because budworm populations remained at damaging levels (Mounts et al., 1978). For these reasons, entomologists do not recommend the use of these chemical insecticides, and therefore this alternative was eliminated from detailed study.

Alternatives Considered In Detail

This part of Chapter II briefly describes four alternatives considered in detail for this EIS. These alternatives were designed to respond to the identified planning questions.

Objectives Used in Designing Alternatives

The issue-driven objectives used in designing all action alternatives (which do not vary significantly between alternatives) include:

1. meeting or exceeding water quality standards;
2. maintaining wildlife habitats and populations;
3. minimizing any potential risks to human health and the human environment;
4. utilizing an effective and economically sound method of management.

Alternative A (No action)

This alternative provides no direct suppression action to reduce the western spruce budworm population to nondamaging levels. The budworm infestation would be allowed to continue until it collapses due to natural factors.

Current management practices in the infested areas would continue. Scheduling and timing of these activities could be affected by the budworm outbreak. Silvicultural prescriptions may be changed to respond to forest stand damage.

Western spruce budworm activity would be monitored annually with an aerial sketchmap survey to determine the extent of visible defoliation.

Alternative B (Preferred)

This alternative would provide direct suppression utilizing the biological insecticide *B.t.*

This short-term alternative consists of suppression projects to protect resource values (commodity and noncommodity) that are truly at risk of unacceptable damage. It would involve the aerial application of the biological insecticide *B.t.* to selected analysis units with the objective of reducing budworm populations to nondamaging levels for at least a major portion of the current outbreak. Depending upon post-treatment rates of population buildup due to resurgence, reinvasion, and unit configuration, retreatment of some areas may be indicated during the remainder of the outbreak to maintain the objective.

Current management practices in the infested areas would continue. Scheduling and timing of these activities could be affected by the budworm outbreak. Silvicultural prescriptions may be changed to respond to damage to forest stands.

Future treatment costs are based on the proportion of acres in an analysis unit that have been infested less than 4 years. Only one treatment is projected on units which have been infested for 4 or more years. Two treatments are projected on recently infested units to effect adequate protection until the outbreak collapses. Units which have a mixture of acres at different years of the infestation may need a second treatment, with success proportional to the number of acres that are newly infested.

Alternative C

This alternative would utilize direct suppression with the use of chemical insecticides.

This short-term alternative consists of suppression projects to protect resource values (commodity and noncommodity) that are at risk of unacceptable damage. Four chemical insecticides, malathion, acephate, mexacarbate, and carbaryl, are currently registered by the Environmental Protection Agency for suppression by aerial application of western spruce budworm. This alternative discusses only the use of carbaryl. At this time, carbaryl is the most acceptable chemical insecticide in terms of efficacy in suppressing budworm populations. Application of carbaryl would involve aerial broadcast treatment of infested areas, while leaving at least a one-swath untreated (buffer) strip on each side of streams and around bodies of water. The objective would be to reduce budworm populations to nondamaging levels for at least a major portion of the current outbreak. Depending upon post-treatment rates of population buildup due to resurgence, reinvasion, and unit configuration, retreatment of some areas may be indicated during the remainder of the outbreak to maintain the control objectives.

Current management practices in the infested areas would continue. Scheduling and timing of these activities may be affected by the budworm outbreak. Silvicultural prescriptions may be changed to respond to damage to forest stands.

Future treatment costs are based on the proportion of acres in an analysis unit that have been infested less than 4 years. Only one treatment is projected on units which have been infested for 4 or more years. Two treatments are projected on recently infested units to effect adequate protection until the outbreak collapses. Units which have a mixture of acres at different years of the infestation may need a second treatment, with success proportional to the number of acres that are newly infested.

Alternative D (Preferred)

This alternative would combine the use of *B.t.* and the chemical insecticide carbaryl.

This short-term alternative consists of suppression projects to protect resource values (commodity and noncommodity) that are at risk of unacceptable damage. This would include the use of *B.t.* up to, but not over streams or other bodies of water. Carbaryl would be used up to a buffer strip along streams or around other bodies of water. *B.t.* could be used in the buffer strips, but not over water in the carbaryl-treated units. The choice of carbaryl or *B.t.* over the majority of the treatment area would be determined on a project-specific basis. The particular attributes of each area, including humans habiting or frequenting the unit, would be considered in the decision.

Current management practices in the infested areas would continue. Scheduling and timing of these activities may be affected by the budworm outbreak. Silvicultural prescriptions may be changed to respond to damage to forest stands.

Future treatment costs are based on the proportion of acres in an analysis unit that have been infested less than 4 years. Only one treatment is projected on units which have been infested for 4 or more years. Two treatments are projected on recently infested units to effect adequate protection until the outbreak collapses. Units which have a mixture of acres at different years of the infestation may need a second treatment, with success proportional to the number of acres that are newly infested.

A comparison of these alternatives follows:

Comparison Of Alternatives

Planning Question #1:

What are the economic implications of the alternatives?

Alt. A. (No Action)	Long-term reduction in future supply of wood fiber; short-term increase of logs for manufacturing due to salvage operations.
Alt. B. (Use of *B.t.* only)	Long-term supply of wood fiber maintained; short-term increases in expenditures to local economies for services rendered.
Alt. C. (Use of Carbaryl only)	Long-term supply of wood fiber maintained; short-term increases in expenditures to local economies for services rendered.
Alt. D. (Use of both *B.t.* and Carbaryl)	Long-term supply of wood fiber maintained; short-term increases in expenditures to local economies for services rendered.

Planning Question #2:

How effective are the treatment methods?

Alt. A. (No Action)	No effect on achieving lasting budworm population reductions.
Alt. B. (Use of *B.t.* only)	Applications are likely to suppress budworm populations below identified threshold levels; populations unlikely to develop a tolerance; resurgence and reinvasion are not anticipated.
Alt. C. (Use of Carbaryl only)	Applications are likely to suppress budworm populations below identified threshholds; budworm populations can develop a tolerance to carbaryl applications; reinvasion may occur from streamside buffer strips; resurgence is a potential problem.
Alt. D. (Use of both *B.t.* and Carbaryl)	Flexibility to utilize both *B.t.* and/or carbaryl as the situation warrants, is likely to suppress budworm populations below identified threshhold levels; reinvasion need not occur; resurgence may occur.

Planning Question #3:

What are the effects of alternatives on other resources?

Alt. A. (No Action)	Implementation of this alternative would not produce adverse impacts to other resources.
Alt. B. (Use of *B.t.* only)	Implementation of this alternative would not produce significant impacts to other resources. Some resources such as general wildlife populations, may benefit slightly.
Alt. C. (Use of Carbaryl only)	Implementation of this alternative may produce significant impacts to some resources. Specifically, some species of small mammals, birds, and insects may

be adversely affected by the toxological properties of carbaryl.

Alt. D. (Use of both *B.t.* and Carbaryl)	Implementation of this alternative, correspondent with established mitigation measures, may result in minor impacts to some resources. Significant impacts would probably be mitigated by the use of B.t. in sensitive ecosystems.

Planning Question #4:

What is the effect of each alternative on visual quality?

Alt. A. (No Action)	Severe defoliation will result in color and texture changes for up to a decade or more; changes to visual quality could result in decreased recreational use, with a coresponding impact on the recreation economy.
Alt. B. (Use of *B.t.* only)	Treatment would provide short-term protection of foliage; changes to color and texture of the landscape are reduced but not eliminated; cumulative mortality and top-kill would be reduced; only slight reductions in recreation user days would be expected; a forest with tree species susceptible to continued defoliation would be maintained.
Alt. C. (Use of Carbaryl only)	Treatment would provide short-term protection of foliage; changes to color and texture of the landscape are reduced but not eliminated; cumulative mortality and top-kill would be reduced; only slight reductions in recreation user days would be expected; a forest with tree species susceptible to continued defoliation would be maintained.
Alt. D. (Use of both *B.t.* and Carbaryl)	Treatment would provide short-term protection of foliage; changes to color and texture of the landscape are reduced but not eliminated; cumulative mortality and top-kill would be reduced; only slight reductions in recreation user days would be expected; a forest with tree species susceptible to continued defoliation would be maintained.

Planning Question #5:

What is the effect of alternatives on fuels and fire?

Alt. A. (No Action)	Minimal impact on fuel loading in areas where only scattered mortality has occurred; severe defoliation and continuous mortality will result in significant increases to fuel loading; fire intensity is expected to be high; fire line construction will be slow.
Alt. B. (Use of *B.t.* only)	Short-term potential for heavy fuel buildup would be reduced or eliminated; scattered mortality would occur; existing fuel loadings would not be significantly increased; projected fire intensity and fireline construction rates would not be slowed.
Alt. C. (Use of Carbaryl only)	Short-term potential for heavy fuel buildup would be reduced or eliminated; scattered mortality would occur; existing fuel loadings would not be significantly increased; projected fire intensity and fireline construction rates would not be slowed.
Alt. D. (Use of both *B.t.* and Carbaryl)	Short-term potential for heavy fuel buildup would be reduced or eliminated; scattered mortality would occur; existing fuel loadings would not be significantly increased; projected fire intensity and fireline construction rates would not be slowed.

Planning Question #6:

What are the hydrological effects of treatment and nontreatment?

Alt. A. (No Action)	No significant increase in annual streamflow or peak discharge is anticipated as a direct result of defoliation and mortality. Cumulative impacts from defoliation and extensive management activities could produce significant increases in annual streamflow. These increases could degrade water quality. Defoliation and mortality could promote slight increases in water temperature in some stream segments.
Alt. B. (Use of *B.t.* only)	This alternative would reduce defoliation while minimizing impacts described in the No-action Alternative.
Alt. C. (Use of Carbaryl only)	This alternative would reduce defoliation while minimizing impacts described in the No-action Alternative.
Alt. D. (Use of both *B.t.* and Carbaryl)	This alternative would reduce defoliation while minimizing impacts described in the No-aAction Alternative.

Planning Question #7:

What is the timeliness of treatment for this and future outbreak cycles?

Alt. A. (No Action)	Implementation of this alternative would allow the budworm infestation to follow its natural course. It would have no effect on the frequency of future outbreak cycles.
Alt. B. (Use of *B.t.* only)	Implementation of treatments prescribed in this alternative is timely. Sufficient time has elapsed to indicate that the outbreak is persisting despite natural enemies. Earlier treatment would not have prevented the "spread" of budworm infestation. The application of *B.t.* should have no effect on future outbreaks.
Alt. C. (Use of Carbaryl only)	Implementation of treatments prescribed in this alternative is timely. Sufficient time has elapsed to indicate that the outbreak is persisting despite natural enemies. The application of carbaryl (with buffers where appropriate) may have an effect on the ability of budworm populations to reinvade and resurge, thus affecting future outbreaks.
Alt. D. (Use of both *B.t.* and Carbaryl)	Implementation of treatments prescribed in this alternative is timely. Sufficient time has elapsed to indicate that the outbreak is persisting despite natural enemies. The application of sublethal dosages of carbaryl may stimulate budworm populations and contribute to the resurgence of vigorous populations.

Planning Question #8:

What are the effects on human health associated with treatments using *B.t.* and other chemicals?

Alt. A. (No Action)	This alternative would have no effect on human health since the alternative does not employ chemical insecticides or biological controls.

Alt. B. (Use of *B.t.* only)	This alternative presents the least risk of the direct suppression alternatives. The use of *B.t.* poses little risk of acute or chronic effects upon human health.
Alt. C. (Use of Carbaryl only)	This alternative presents the highest risk to human health of the direct suppression alternatives. Carbaryl poses a human health risk only in the case of accidents. The petroleum distillate carrying agents (kerosene and diesel oil) commonly used for application present a risk under routine worst-case conditions, and in the case of accidents.
Alt. D. (Use of both *B.t.* and Carbaryl)	This alternative presents human health risks of an intermediate nature. Risks would be reduced to the extent that *B.t.* is used instead of carbaryl.

Chapter 3: Affected Environment

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CHAPTER III. AFFECTED ENVIRONMENT

Introduction

Area Affected

Chapter III describes the environment that would be influenced by the implementation of any of the alternatives. The environmental factors discussed are those which are significant and pertinent to issues, and concerns, including the physical, biological, economic, and social aspects. This chapter describes the interaction of the resources, protective environmental considerations, commodity outputs, potential outputs, and changes and trends. It also provides the basic information relating to the issues and concerns.

Location

The Pacific Northwest Region (Region 6) includes the States of Oregon and Washington, as well as small portions of northern California and western Idaho. The Region covers a total area of 106 million acres. The USDA Forest Service administers 24.5 million acres of this area, divided into 19 National Forests and 1 National Grassland. The Forest Service also assists in the protection and management of 20.5 million acres of other commercial forest lands through cooperative programs with private and corporate landowners, as well as State and local governments. Much of this ownership is an intermingled checkerboard pattern of ownership.

Water Quality/Quantity

Current Conditions

The National Forests occupy 23 percent of the land in the Pacific Northwest, yet 44 percent of the region's water supply originates on National Forest land. There are 112,000 miles of streams and approximately 216,000 surface acres of lakes and reservoirs which produce 75 million acre-feet of water. There are thousands of acres of wetlands and floodplains which provide unusually diverse habitat, particularly where the riparian and terrestrial ecosystems meet.

About 6 million acres, approximately one-quarter of National Forest lands, are administered specifically as domestic watersheds. About 800,000 acres are managed according to formal agreements with 15 municipalities. Many of the agreements list specific restrictions. For example, the cities of Ashland, Medford, Portland, Seattle, and The Dalles prohibit or severely restrict the use of pesticides. There are approximately 60 additional watersheds managed for individual use, ski areas, etc., which have no formal agreement. Other uses include irrigation, hydroelectric generation, and fish production.

Water Quality

The quality and quantity of water produced by the National Forests is dependent upon the management of vegetation and soils in each watershed. Managing streamside vegetation, roadside vegetation (particularly during and shortly after construction), and vegetation in harvest units is key to maintaining water quality.

Sediment is the primary polluting factor reducing water quality. Erosion from road construction, harvesting, landslides, and natural sloughing of streambanks is the major source.

Water quality in National Forest streams is generally excellent. For example, water from the Bull Run watershed which supplies the city of Portland, requires little treatment.

Cooperation With Other Agencies

Federal agencies with responsibilities involving water resources include the Environmental Protection Agency, Army Corps of Engineers, United States Geological Survey, and the Soil Conservation Service.

Washington State agencies include the Washington Department of Game, Washington Department of Ecology, Washington Department of Fisheries, and Washington Department of Natural Resources.

Oregon State agencies include the Oregon Department of Environmental Quality, Oregon Department of

Forestry, Oregon Water Resources Department, Oregon Department of Lands, and Oregon Department of Fish and Wildlife.

The North Coast Regional Water Quality Control Board (California) and the California Department of Fish and Game are also involved with management of water resources in the region.

Geology

Water, volcanic activity, and glacial events in the region have created a great variety of landforms, ranging from coastal dunes and flat grasslands to rolling hills and steep, highly dissected hillsides.

The major geological feature in the region is the Cascade Range, which parallels the Pacific coastline about 100 miles inland. Volcanic peaks over 10,000 feet in elevation regularly punctuate the length of the Cascades. The main crest averages about 6,700 feet, a significant barrier to cyclonic marine storms. Drier weather on the east side of the crest is attributed to its rain shadow.

The Coastal Range lies west of and parallel to the Cascades. This area is much lower in elevation (about 3,000 feet). Forests west of the Cascade crest are wet, with relatively even temperatures characteristic of a marine-dominated climate.

The Coastal Range and the Cascades break the region into four areas that have similar topographic features, and climate. These areas are the Coastal, Western Cascades, Transition, and East-side areas.

The geology of the region is dominated by Cascade volcanism, and local intrusions of igneous rocks, faulting, uplift, and metamorphism.

Sediments of the Coastal forests are generally porous, erode easily, and are prone to mass movement. The Klamath Geological Province (Siskiyou National Forest) and the Olympic area, however, are much more complex.

The Cascade, Transition, and East-side forests are commonly basalt or andesite (extruded fine-grained lava), but a significant portion of the East-side has been covered by ash and pumice during recent volcanic eruptions. The basalts are relatively stable and fertile, but the ash and pumice are infertile and erodible.

The Blue Mountains and Wenatchee Mountains are distinctly more complex than the rest of the East-side forests. The old limestones, mudstones, and sandstones of the Blue Mountains can be locally unstable.

Soils

Soils take on many of the characteristics of the rock from which they are formed. For example, serpentinites in the Wallowa-Whitman, Wenatchee, and Siskiyou National Forests produce nutritionally unbalanced, unproductive, and unstable soils. Ash and pumice deposits from the eruptions of Mount Mazama (which created Crater Lake), and more recently from Mount St. Helens, offer more nutritional balance than serpentinites, but are relatively sterile and erodible.

Soil texture and surface conditions are related to soil porosity, infiltration, and percolation rates. These variables relate to the fate of chemicals in the soil system and the productivity of the site. However, they must be analyzed on a site-specific basis. Few characteristics are common throughout the region. Granitic materials and sandstones, however, are often very coarse and porous.

Soil depth, texture, and productivity vary throughout the region. Some of the deepest, most productive forest soils are found in the lower and gentler slopes of the Cascade and Coastal forests below the 2,000-foot elevation.

Climate

Winter storms and the summer Pacific high pressure area are the dominant regional climatic features. The winters are notably wet (typically 80 percent of the total annual precipitation falls in winter), and the dry summers are inconsistently interrupted by localized thunderstorms, particularly in the Transition and East-side forests.

High rainfall (over 150 inches at the coastal crest), and summer fog keep the Coastal forests wet most of the year. Temperatures are moderate. Freezing temperatures and snow are experienced only during midwinter.

Cascade forests receive from 100 inches of annual precipitation on the Rogue River and Umpqua National Forests to over 150 inches on the Gifford Pinchot and Mt. Baker-Snoqualmie National Forests. Snowpacks last well into summer, feeding many permanent streams. Late spring frost is common.

The rain shadow produced by the Cascades reduces the annual rainfall significantly in the Transition forests. Because the moderating marine influence wanes at the Cascade Crest, average annual temperatures can be 10 degrees Fahrenheit lower than Cascade sites.

Precipitation on the East-side forests is less than 20 inches annually in some areas. However, most of the forests are located on mountain ranges or uplands (the Wallowa Mountains, the Blue Mountains, and the Okanogan Highlands), and precipitation increases with elevation, as does the potential for summer lightning storms. Summers are hot and dry. Frost can occur any time of year.

Vegetation

Plant Communities

All true fir and Douglas-fir stands are potential hosts for western spruce budworm. The current epidemic is located primarily on the east side of the Cascade Range. Discussion of vegetation will primarily focus on that area, although the West-side true fir and Douglas-fir stands will also be discussed.

The forest ecosystem is in a constant state of change. The process where one type of plant community replaces another without catastrophic disturbance is called succession. Plant communities are composed of several different layers of vegetation; trees in the upper and lower canopy, a brush and shrub layer, and a grass and forb layer. All the different plants in these layers have a relationship to and effect on the ecosystem.

In the temperate coniferous forest ecosystem, a forest which began as an even-aged stand of a pioneer species, such as aspen or lodgepole, changes to an uneven-aged forest of various conifer species, primarily Douglas-fir and grand or white fir, as a result of natural succession. Examples of intermediate species in this succession are ponderosa pine and western larch.

Fire is a catastrophic disturbance which interrupts succession, and has played a distinct role in the ecosystem development of the forests. In the ponderosa pine timber types, vegetation has evolved to accommodate a fire ecology. The historic park-like stands of ponderosa pine with an open grassy understory were maintained, in great part, by fire.

There are two types of fires which produce different results: high intensity conflagration fires and low intensity ground fires.

In East-side forest plant communities, areas subjected to high intensity fires in the past are now dominated by western larch, lodgepole pine, or a western larch/fir mixture. West-side stands, following conflagration fire histories, are Douglas-fir, true fir, and hemlock communities. These fires tended to occur on northerly or easterly slopes. Because of higher fuel moisture retention, fuels on these slopes were not as susceptible to low intensity ground fires and did not burn often. These fuels built up over time, until a drought year combined with a natural or human-caused ignition. These fires probably did not occur more than once every 15 to 25 years on the east side of the Cascades. On the west side of the Cascades, high intensity fire frequency ranged from every 50 to 300 years. In both cases, the fires were devastating to large acreages of forest and range.

Low intensity ground fires produced a totally different effect in the forest environment. This type of fire normally occurred in the ponderosa pine plant community type. Based on fire scars in ponderosa pine, it is estimated that low intensity fires occurred on an average of once every 10 years. These fires resulted in nonselective thinning of young ponderosa pine, selective elimination of white fir and Douglas-fir, and maintained a rather open spacing of trees.

Interactions

The vegetative composition of National Forests has changed greatly during the last century. These changes are especially evident on the East-side Forests. Heavy grazing by horses, sheep, and cattle at the turn of the century tended to increase the early stages of forbs and grasses. Aggressive fire prevention and suppression practices over the past 80 years helped to convert open grasslands to tree-growing sites, and open pine stands to thickets of mixed conifer species. In other areas, the late seral stages of tree species were greatly increased later in the 1950's and 1960's by logging practices which selectively removed the ponderosa pine.

The change in species composition from ponderosa pine to white fir or Douglas-fir is accompanied by increased susceptibility to insects and disease. Insects and disease are not new to the forests, but as their host types increase, the potential for their occurrence also increases.

The increase in host type is not the only factor in the current western spruce budworm outbreak. Most of the understory stands of white fir and Douglas-fir have been suppressed by the ponderosa pine overstory. Removal of the pine overstory has not released the firs to grow freely. The shade-tolerant understory is dense and slow-growing. The poor health of these stands, compounded by the present drought cycle, has resulted in thousands of acres of susceptible host trees.

The characteristics of site and stand that affect susceptibility to budworm have been described (Wulf and Cates, 1985):

Regional climate--General climate significantly affects budworm dynamics. Climate tends to be cool and moist where outbreak frequency is low, but warm and dry where outbreak frequency is high (Kemp, 1983).

Site climate--Given that the regional climate is favorable to budworm, stands on warm, dry sites are the most susceptible. Warm, dry conditions accelerate larval development and tend to stress host trees.

Species composition--Stands composed primarily of host species are more susceptible than mixed stands because more food is available to developing larvae and more sites are present for egg deposition. Furthermore, stands composed primarily of host species that are shade-tolerant tend to be more susceptible than stands that have a sizable component of shade-intolerant host species.

Stand density--Dense host stands are more susceptible than relatively open stands because of increased foliar biomass and increased water and nutrient stress.

Height-class structure--Multistoried stands are more susceptible than one-storied, even-aged stands. The lower stories significantly reduce mortality of dispersing larvae and provide additional substrate.

Vigor--Stressed stands with low vigor tend to be more susceptible, and we believe the quality of the foliage as insect food is enhanced. Low-vigor stands tend to have an altered terpene regime that apparently weakens tree resistance.

Maturity--Older, mature host stands tend to be more susceptible than young stands.

Surrounding host type--Stands in close proximity to forests composed of host species tend to be more susceptible than relatively isolated stands. The probability of adult or larval invasion is much higher when large quantities of a suitable host are nearby.

Insect-caused tree mortality on the forests has been heavy during the past 20 years. Primary causal agents have been Douglas-fir tussock moth, mountain pine beetle, and western spruce budworm. Currently, western spruce budworm and mountain pine beetle are causing the largest amount of mortality.

Timber

Current Conditions

Much of the land within the National Forests of the Pacific Northwest Region is among the most productive forest land in the world. Roughly 90 percent of the National Forest lands are forested. Of this, approximately 76 percent (18.5 million acres) has a productivity level equal to or exceeding 20 cubic feet of wood growth per acre per year. Timberlands have traditionally been divided into two broad subregions: the Coastal and Western Cascades subregion and the East-side and Transition subregion.

Demand for timber will vary with market and economic conditions, and is affected by short-term decisions of other industrial and agency forest ownerships. As a general situation, however, there are purchasers for all volumes made available for harvest. Sale of timber from forests will fluctuate somewhat on an annual basis according to national administrative and budget priorities.

Recent trends of both harvest levels and acres available for harvest (the systematic removal of products) are reflected in Forest land management planning processes. While conditions vary from Forest to Forest, the trend is for somewhat reduced programmed harvest levels in comparison with recent historic levels. For example, it is estimated that annual timber harvest (Allowable Sale Quantity) will be in the range of 3.8 to 4.3 billion board feet following implementation of the 19 Forest land management plans currently in preparation.

Recent additions to the Wilderness System, allocations to protect sensitive resources, and analysis of costs have reduced the amount of timberland in the "base"; programmed harvest levels reflect this. Harvest of timber from all Forests, however, will continue to be a valuable and significant activity.

In some situations, the removal of forest trees is the mechanism for achieving habitat enhancement, visual quality, forest protection, and other management objectives. In these cases, timber yields are the by-product of projects to enhance other resource values. Timber harvest results in manipulation of forest density, species composition, horizontal or vertical distribution, and lesser vegetation.

Insect And Disease Complex

Protection of the Forests from damage is a goal of the Forest Service. Among natural destructive agents, insects rank with fire, disease, and wind in potential for damage to the Forests. Before humans entered the forests of the northern interior West, climatic and geological events, insects, disease, animals, and fire interacted with each other, and with vegetation, to influence forest development.

Silvicultural measures are available for managing some of the diseases on the Forests. The only practical measures for managing most diseases include

removal of infected trees, cultural activities that improve tree vigor, selection of less susceptible tree species, and practices that reduce the probability of mechanical damage. Disease losses are expected to be reduced over time as timber stands are replaced by healthy, young, mixed tree species.

Insects and disease, as well as fire, have a natural role in the forest. Under normal endemic conditions, insects are nature's managers of healthy forests. They work quietly to keep young stands thinned.

Most western forest insects are native and widely distributed. Their role is complex and ranges from benefactor to malefactor. The beneficial and innocuous insects are, by far, the most abundant. The destructive insects receive the most attention because they affect people most directly (Furniss and Carolin, 1977).

Diseases also have a place in altering stand composition. They discriminate against some tree species and allow other species to take their place. Most diseases are opportunistic, taking advantage of the right environmental situation to gain a foothold in the host and perpetuate themselves by seeds or spores. Infection of wounds by microorganisms is a major cause of defect, death, and decay of all species of trees.

Many times, damage by a pest creates a situation so favorable to other pests that, often, more serious damage results from the second pest. Defoliators, for example, often cause varying degrees of crown defoliation which results in dead tips of lateral branches, dead tops, stem deformity, and loss of radial and height growth for a few years. Mortality as the result of very heavy to complete defoliation is an exception. In general, the more serious consequences of defoliation are subsequent deadly attacks of bark beetles. Dead tissue also becomes an entry point for stem rots. Bark beetle attacks in lodgepole and ponderosa pine may not be severe enough to kill the tree, but may introduce blue stain fungus. Death of a tree from root rot may progress slowly, but the weakened tree may attract enough bark beetles to cause its death within a couple of months. Pockets of beetle-killed timber are usually root rot infestation centers which attract bark beetles to the weakened trees. Diseased, defoliated, injured, or otherwise unhealthy trees emit a chemical odor which attracts bark beetles. After a certain number of beetles have already entered a tree, subsequent arrivals will attack nearby healthy trees.

Forest insects and diseases cause the loss of more timber in the United States annually than fires do. During the past 15 years, the East-side forests have been impacted by the Douglas-fir tussock moth *(Orgyia pseudotsugata)*, mountain pine beetle *(Dendroctonus ponderosae)*, western spruce budworm *(Choristoneura occidentalis)*, and larch casebearer *(Coleophore laricella)*. These attacks have been followed by more mortality caused by Douglas-fir bark beetle and the fir engraver beetle; and the less spectacular losses associated with the western pine beetle, Ips beetle, western dwarf mistletoe, and stem and root diseases.

Douglas-fir Tussock Moth

The Douglas-fir tussock moth, *Orgyia pseudotsugata*, is an important defoliator of true firs and Douglas-fir in western North America. The name of this insect, "tussock moth", is derived from the brushes of body hairs on the larvae. Damage to the host is caused by the feeding of the larvae, first on the new current year's foliage and then on old foliage. Defoliation occurs first in the tops of trees and branch tips, and then in the lower crown and further back on the branches. As defoliation progresses, the trees show a brownish color due to the exposure of the twigs and branches.

Defoliation by the tussock moth kills or top-kills many trees, weakens additional trees that are eventually killed by bark beetles, and retards tree growth for several years. For example, a very large outbreak in Oregon and Washington recently, killed 39 percent of all trees in the heavily defoliated areas. Within these areas were patches where nearly all the trees died. Top-kill in the heavily defoliated areas amounted to 10 percent of the grand fir and 35 percent of the Douglas-fir.

Although the tussock moth is no longer abundant and is often hard to find, the legacy of the outbreak is still visible. Severe defoliation resulted in widespread top-killing and large numbers of dead trees. Many trees that were not initially killed by the tussock moth were later killed by bark beetles.

Interactions

The Douglas-fir tussock moth and the western spruce budworm are both defoliators with spasmodic periods of outbreak. The host species for both insects is largely the same. The combined effect of stressed and weakened host trees is a primary casual agent in bark beetle epidemics.

Mountain Pine Beetles

Dendroctonus (meaning tree killer) beetles, particularly the mountain beetles, have been dramatic mortality agents on the forests. The mountain pine beetle outbreak in eastern Oregon was first identified in 1968 on the Wallowa-Whitman National Forest.

The outbreak was fueled by extensive stands of mature, overstocked, and stagnated lodgepole pine. Harvest, with prompt regeneration of the lodgepole pine stands within the mountain pine beetle epidemic area, has been a preferred method of handling the infestation. The lodgepole pine salvage program is expected to decline in the next 5 to 10 years as remaining material deteriorates.

Interactions

Western spruce budworm occasionally feed on, or are associated with a variety of western pines. Damage caused by the spruce budworm is generally not fatal. When damage occurs, the stressed trees become more susceptible to infestation by mountain pine beetle. This indirect association can produce a significant effect on lodgepole pine stands.

Douglas-fir Beetle

The Douglas-fir beetle, *Dendroctonus pseudotsugae*, is the most important bark beetle pest of Douglas-fir throughout the range of this tree in the western United States, British Columbia, and Mexico. It also attacks western larch. Endemic populations of beetles normally attack and kill small groups of trees which are diseased, injured, or have been felled. At times, epidemic populations develop in abundant susceptible hosts and then spread to adjacent green, apparently healthy trees. These epidemics usually develop following extensive natural or human-caused disturbances such as windthrow, fire, defoliation, or widespread cutting.

Interactions

There is a relationship between beetle outbreaks and outbreaks of defoliating insects, the Douglas-fir tussock moth, and western spruce budworm. Following each incidence of heavy defoliation there has been a corresponding increase of bark beetle activity.

Larch Casebearer

The larch casebearer is a European insect that became established in New England prior to 1886. In the West, it was discovered on western larch in northern Idaho in 1956. The principal damage is caused by the larvae feeding on new foliage in early spring. Repeated defoliation for several years significantly reduces diameter growth and weakens trees so that they may die from other causes (Furniss and Carolin, 1977).

Interactions

The larch casebearer and the western spruce budworm are both defoliators with spasmodic periods of outbreak. The host species for both insects is largely the same. The combined effects of stressed and weakened host trees is a primary causal agent in bark beetle epidemics.

Miscellaneous Forest Insects

Other insects that cause mortality or disrupt management opportunities are the pine butterfly *(Neophasia menapia)*, fir engraver *(Scolytus ventralis)*, pine engraver *(Ips pini)*, and the western pine beetle *(Dendroctonus brevicomis)*.

Forest Diseases

Laminated root rot *(Phellinus weirii)*, shoestring root rot *(Armillaria mellea)*, and brown root or butt rot *(Fomes annosus)* are the most significant root rots which cause localized mortality and may affect future management of young stands. Fungi which promote decay, such as *Fomes annosus*, may cause substantial losses of volume if trees are wounded during logging. Brown stringy rot *(Echinodontium tinctorium)*, an important heart rot, commonly infects grand fir, white fir, and subalpine fir, causing heavy defects in overmature timber stands. Dwarf mistletoe *(Arceuthobium sp.)*, infects Douglas-fir, western larch, lodgepole pine, and ponderosa pine. This parasitic plant weakens trees, causes deformity, and reduces growth.

Laminated Root Rot

Laminated root rot, caused by the fungus *Phellinus weirii*, is the most damaging disease to Douglas-fir in the Pacific Northwest, causing growth loss, and eventually, death of infected trees. It is responsible for an estimated annual loss of 32 million cubic feet of timber in western Oregon and Washington. The magnitude of loss on interior mixed conifer stands is estimated to be **about 40 percent of total mortality** based upon preliminary surveys conducted on the Fremont and Ochoco National Forests (Schmitt, C.L., et al.). This disease can infect all conifers but some tolerate the pathogen more than others. Readily infected and killed (highly susceptible) are Douglas-fir, mountain hemlock, white fir, and grand fir. Often infected but rarely killed (intermediately susceptible), are western hemlock, western larch, Pacific silver fir, subalpine fir, California red fir, and

the spruces. Seldom infected and almost never killed (tolerant or resistant) are the pines and cedars.

Interactions

Phellinus weirii extensively decays roots of highly susceptible host trees and either causes windthrow or kills by destroying their ability to take up water and nutrients. Trees which are also under stress by spruce budworm defoliation are more susceptible to mortality than nonhost species. In addition, these trees are predisposed to bark beetle attack.

Armillaria

Armillaria root disease in conifers, caused by the fungus, *Armillaria obscura*, is the most common and widely distributed forest root disease in Oregon and Washington. All conifers can be damaged by this disease, but there are differences in degree of susceptibility and damage expression.

In forests east of the Cascade Range crest, damage caused by Armillaria root disease starts to become apparent at age 5, and may continue throughout the life of the stand. Habitat type has been found to influence the presence of Armillaria root disease in northern Idaho and eastern Oregon and Washington. The fungus is nearly always present in plots established in cool and moist to warm and moist habitat types, and is always absent in cold and dry, hot and dry, and frost-pocket habitat types. Armillaria root disease is less likely to be found on high-productivity sites containing grand fir, western red cedar, and western hemlock climax series than on low-productivity sites with subalpine fir and Douglas-fir climax series. Douglas-fir, grand fir, and subalpine fir showed the highest levels of infection when they were the climax species. The probability of finding pathogenic Armillaria on the high-productivity habitat types was higher on plots that had human-caused disturbance than on undisturbed plots.

Interactions

Tree mortality is the most common form of damage caused by Armillaria root disease. Affected trees can be windthrown, but tend to die standing. Various species of bark beetles, particularly fir engravers (*Scolytus ventralis*) in white fir and grand fir, will attack trees weakened by Armillaria root disease and may hasten tree mortality. Tree killing by Armillaria root disease will often increase 1 to 2 years after severe droughts or nearly complete defoliation by insects. *A. obscura* is able to break out of callus tissues on roots and spread rapidly when trees are severely stressed or when they are cut.

Armillaria root disease centers develop when neighboring trees are infected and killed over many years. Expansion rates probably average 1 foot per year, but may be 2 to 3 feet in some stands. Disease centers often contain infected old-growth stumps, the original source of infection, and trees in several stages of deterioration. Fortunately, some disease centers become inactive and damage subsides.

In addition to tree mortality, Armillaria root disease can cause butt rot and reduction of growth. If a tree is not directly killed, a compartmentalized root and butt rot may occur, especially in nonresinous conifers such as hemlock and true firs. The amount of bark killing and associated internal decay are dependent upon innoculum potential, tree vigor, tree age, tree species, and host genetics.

Fomes annosus

Annosus root and butt rot, caused by the fungus *Fomes annosus*, causes tree mortality, butt rot, susceptibility to windthrow, and slowing of growth of affected trees.

All conifers can be infected by *F. annosus*, but there are differences among species in degree of susceptibility and damage. In the Pacific Northwest, western hemlock, mountain hemlock, grand fir, white fir, and Pacific silver fir are highly susceptible to infection and can be severely damaged; ponderosa pine, lodgepole pine, noble fir, subalpine fir, and California red fir are moderately susceptible and sometimes damaged; and Douglas-fir, western redcedar, incense cedar, Port Orford cedar, western larch, western white pine, sugar pine, Englemann spruce, and Sitka spruce are slightly susceptible and rarely damaged. Hardwoods are not damaged in the Pacific Northwest. Apparently, different strains of *F. annosus* have rather specific host preferences. There is strong evidence, for example, that the fungus will not spread from white fir stumps to ponderosa pine and vice versa.

Interactions

Fomes annosus causes tree mortality and wood loss through decay. Tree death is the usual result of infection in resinous hosts and in white fir and grand fir in southeastern Oregon. Trees killed by annosus root disease tend to die standing rather than be windthrown. Mountain pine beetles (*Dendroctonus ponderosae*) and western pine beetles (*D. brevicomis*) often attack infected pines, and attacks by fir engraver (*Scolytus ventralis*) are common on infected true firs.

Armillaria root disease is also frequently found on trees infected by *F. annosus*.

Hemlocks are much more likely to suffer butt decay than to be killed by *F. annosus*. Most decay will be associated with wounds and will be confined to woody tissues present when the trees were wounded. Losses due to annosus butt decay in hemlock stands tend to be small unless trees are older than 120 years or have been badly wounded.

Indian Paint Fungus

Indian paint fungus, or brown stringy rot, caused by *Echinodontium tinctorium*, is responsible for nearly 80 percent of the decay in old-growth grand fir stands in eastern Oregon and Washington. Cull material, primarily caused by decay, approached 40 percent of the total board-foot volume in mature and overmature grand fir in the Blue Mountains of Oregon. True firs and hemlock are the primary hosts of this disease; Douglas-fir and spruce are rarely infected.

Brown stringy rot is most common in the mid-trunk region, but may extend into the butt or down from the top. Advanced regeneration may have significant volume losses caused by decay initiated by management activities.

Wildlife And Wildlife Habitat

Current Conditions

Forests of the Pacific Northwest Region are known to provide habitat for 569 species of resident and migratory, terrestrial vertebrate wildlife (174 mammals, 335 birds, and 60 reptiles and amphibians). Lists of species and habitat relationships can be found in Thomas (1979), Thomas and Maser (1983), and Brown (1985).

Public demand for wildlife resources is measured by consumptive (hunting) and nonconsumptive (viewing) uses. Wildlife and Fish User Days (WFUD's) are used to report the demand for these resources. The most recent summary of these values (Annual Fish and Wildlife Report, 1984), shows that 8.3 million WFUD's were attributed to the wildlife resource.

Interactions

In order to maintain viable, self-sustaining populations of wildlife, an appropriate amount and distribution of suitable habitat must exist. The amount and distribution of habitat will vary over time. Changes in habitat condition and suitability can occur abruptly (as the result of fire, windstorm, or timber harvest), or more gradually (as in the slow replacement of plant communities characteristic of succession).

Wildlife Relationships To Successional Stages

On forested sites, six different successional stages (or stand conditions) are usually recognized: grass-forb, shrub, open sapling-pole, closed sapling-pole, mature, and old growth (Brown, 1985). Each successional stage in each forest community supports a characteristic grouping of wildlife species.

While contrasts among successional stages are less dramatic in the grass-shrub ecosystems, similar relationships between wildlife and vegetation characteristics apply. Some plant communities, such as wet meadows, may show little evidence of change over time.

Some species find suitable habitat in a wide variety of plant communities and stand conditions, while others favor specific plant communities and stand conditions. Species with specific habitat requirements are generally less tolerant to changes in vegetation.

Deer and elk use many plant communities--shrub through old-growth successional stages--for hiding and/or thermal cover. Depending upon environmental conditions and forage availability, they feed in a wide variety of plant communities and stand conditions. These species are relatively tolerant of changes in habitat conditions.

The western red-backed vole and northern spotted owl are dependent upon older, closed-canopy forest stands. These species are sensitive to changes in stand conditions. Their population levels could drop dramatically as stands are converted to younger age classes.

In grass-and shrub-dominated areas east of the Cascades, sage grouse breed only in areas with sagebrush, while green-tailed towhees utilize several communitiescontaining various tall shrubs or trees.

In the absence of human manipulation, natural landscapes support characteristic patterns of plant communities and stand conditions. These reflect, in part, the frequency of disturbances, site productivity, and successional changes that occur over time.

Most forested sites historically experienced stand-replacing fires at intervals of several hundred years. The long intervals between such events, combined with the longevity of trees such as Douglas-fir and the fire resistance of such trees as oak

and ponderosa pine, led to a landscape comprised largely of mature and old-growth stands (Harris 1984).

As a result of clearing, logging, and wildfire, much of the forest land in Oregon and Washington is currently occupied by younger stand conditions. Some wildlife populations will increase as forested lands return to early successional stages, and those that thrive in older forests will decline.

In the grass-and shrub-dominated plant communities characteristic of the Columbia Plateau, climate, soils, and fires occurring at relatively frequent intervals, tended to favor grasses over shrubs.

In the Great Basin, large sagebrush communities predominate. Fire suppression and grazing favor dominance of shrubs and juniper, with a corresponding shift in wildlife populations. These trends have been somewhat counterbalanced by practices (such as brush control projects) that are intended to maintain grass/forb-dominated plant communities.

Interactions

Wildlife distribution and abundance are influenced by vegetation, but animals can also affect distribution and abundance of vegetation. Animals can carry and distribute seeds, and thus determine where plants grow. Grazing and browsing by wildlife can affect plant growth and vigor, including that of young trees.

Many wildlife species including bear, deer, elk, mountain beaver, porcupine, hares, rabbits, and various small rodents can have adverse effects on the survival and growth of conifers. Conversely, wildlife may browse vegetation that competes with conifer seedlings, and foraging by many bird species may provide natural control of insects which damage many conifer stands. Animals also play a vital role in dispersing spores of fungi essential to tree growth (Maser, et al., 1978).

Cooperation With Other Agencies

Management of wildlife populations involves a partnership between State and Federal agencies. The Pacific Northwest Region has developed Memorandums of Understanding with the Oregon Department of Fish and Wildlife and the Washington Department of Game to facilitate the development of common goals and management strategies for the wildlife resource. These agreements provide opportunities for cooperative interagency planning, funding, and implementation of projects designed to benefit wildlife populations.

Threatened, Endangered, and Sensitive Animal Species

Current Conditions

Six wildlife species currently listed by the U.S. Fish and Wildlife Service as endangered or threatened under the Endangered Species Act are known or suspected to occur on National Forest lands in the Pacific Northwest. These species and their status are listed in Table III-III.

These species differ widely in their distribution in the Northwest. The brown pelican is known only from coastal portions of the Siuslaw National Forest. Woodland caribou occur only on the Colville National Forest. In the State of Washington, grizzly bear and gray wolf have documented or suspected occurrences in four and five Forests, respectively, Peregrine falcons are known to have nesting, winter roosting, or migratory sites on all 19 Forests.

Thirty-six other species (8 mammals, 14 birds, 1 reptile, 3 amphibians, and 10 fish) are included on the Regional list of Sensitive Species. This list includes species considered by the States of Oregon or Washington to be threatened or endangered, and species under review by the U.S. Fish and Wildlife Service.

Interactions

All Forest Service activities that might disturb these species or their habitat must be preceded by a biological evaluation (Forest Service Manual 2670). This process should determine whether these species or their habitats are present in the project area, and if so, whether there are potential adverse effects on the sensitive species. Mitigation measures or project modification may then be planned, as appropriate.

Cooperation With Other Agencies

Whenever proposed Forest Service projects may affect any of these species, consultation is initiated with the U.S. Fish and Wildlife Service to assure that activities will not jeopardize continued survival of the species. The Forest Service also cooperates with other Federal agencies and State wildlife agencies in efforts to improve habitat for these species. Cooperative efforts to reintroduce some of these species into portions of their former ranges are also underway.

Threatened, Endangered, and Sensitive Plant Species

Current Conditions

On National Forest lands in Oregon and Washington, only one plant species currently listed under the Endangered Species Act is known to occur. MacFarlane's four-o'clock *(Mirabilis macfarlanei)* is listed as endangered. It is known to occur at only a few locations in the Snake River country of Oregon and Idaho. When a listed species may be affected by planned Forest Service activities, consultation is initiated with the U.S. Fish and Wildlife Service to assure that activities will not jeopardize the continued survival of the species.

More than four hundred plant species are currently included on the Regional Forester's list of sensitive species, or are considered as potential additions to that list. These species are considered to be endangered, threatened, or sensitive by the States of Oregon and Washington; or are under review by the U.S. Fish and Wildlife Service.

These species include the full range of vascular plants, from grapeferns and club mosses to orchids and grasses. They occupy a wide variety of habitats. Often they occur in less common habitat areas such as in wetlands, riparian areas, rock outcrops, or in soils derived from unusual parent material, such as serpentine. Sensitive plant species can be found throughout the region. Particularly high concentrations are known to occur in the Siskiyou, Wenatchee and Wallowa Mountains, and the Columbia River Gorge.

Interactions

All Forest Service projects that might disturb these species or their habitat must be preceded by a biological evaluation (Forest Service Manual 2670). This process should determine whether these species or their habitats are present in the project area, and if so, whether there are potential adverse effects on the sensitive species. Mitigation measures or project modification may then be planned, as appropriate.

Cooperation With Other Agencies

When a listed species may be affected by planned Forest Service activities, consultation is initiated with the U.S. Fish and Wildlife Service to assure that activities will not jeopardize the continued survival of the species.

Fisheries

Current Conditions

The Pacific Northwest Region has approximately 15,000 miles of streams that directly support both resident and anadromous fish. There are approximately 150,000 acres of lakes and 65,000 acres of reservoirs that can support both warm and cold water species of fish. These aquatic habitats range from estuaries on the Siuslaw National Forest to alpine lakes along the Cascade Crest.

Resident game fish include rainbow, eastern brook, Dolly Varden, and cutthroat trout; crappie; bluegill; yellow perch; smallmouth and largemouth bass; Kokanee; and mountain whitefish. All are highly valued as recreational fish.

Anadromous fish (fish that spawn in fresh water and migrate to the ocean to mature) have both sport and commercial value. They are found on 15 of the 19 Forests in the Region. Pink, chum, coho, sockeye, and chinook salmon; steelhead; and sea-run cutthroat trout depend on streams in the region for spawning and rearing habitat.

Interactions

Pest (management) activities have the potential to affect fish habitat characteristics such as water temperature; sediment load; turbidity; water quantity, timing of flows; and the character of streamside vegetation. Particularly important are management practices within the riparian zone (the interface between terrestrial and aquatic ecosystems).

Cooperation With Other Agencies

The Pacific Northwest Region has agreements with the Washington Department of Fisheries, the Washington Department of Game, the Oregon Department of Fish and Wildlife, and the State of California Department of Fish and Game concerning protection and maintenance of viable habitat for fish and wildlife.

Visual Resources

Scenic diversity in the Pacific Northwest Region contributes greatly to the recreational value of the Forests. A few examples of this diversity include coastal forests, jagged peaks in the North Cascades, the high desert of central Oregon, moss-draped trees in

the Olympic rain forest, and the Blue Mountain and Snake River areas.

The American public expects to see a natural-appearing landscape. This type of landscape exists on most of the Forests. The landscape management objective is to manage all National Forest System lands to attain the highest possible visual quality compatible with other appropriate public uses, costs, and benefits.

Sightseeing is an important component of Forest recreational activities. Most of this activity occurs along major road, trail, and river corridors. Areas that can be seen from these travelways are called viewsheds.

Past land management activities have not extensively disturbed the visual resource. Management practices which result in alterations to the landscape include harvest activities, creation of utility corridors, prescribed fire and fire suppression, and construction of recreational facilities. Maintaining high visual quality tends to reduce timber harvest levels, and increase timber management and road construction costs. Since maintaining a natural appearance often requires retention of large trees and snags, benefits to some species of wildlife are significant.

Interactions

Spruce budworm infestations may cause "browning" or defoliation of the forests, which may cause public concern. Recent examples of insect infestation effects on visual quality are the lodgepole stands suffering from the current mountain pine beetle attack on the Deschutes, and the tussock moth epidemic in the 1970's on the Wallowa-Whitman. At the present time, a widespread western spruce budworm infestation is resulting in thousands of acres of dead foliage and trees in eastern Oregon and Washington.

Salvage efforts often follow these natural occurrences. Salvage removes dead and down material for lumber and chip markets and reduces the potential for catastrophic wildfire. These salvage programs have reduced the visual quality on some corridors.

Cultural Resources

Cultural resources are artifacts, buildings, or sites resulting from human activity in a past era. They can be archaelogical (generally associated with Native Americans), or historical (associated with early settlement and development). Examples of cultural resources are footpath and wagon road remnants, and abandoned trading posts and homesteads.

Interactions

Construction of helicopter landing sites has the potential to impact cultural resources.

Cooperating with Other Agencies

Cultural resources are irreplaceable finite resources. They can have historical, archaelogical, architectural, scientific, information, or cultural values of great interest and concern to the public. Faced with the possible loss of these important treasures, Congress has acted to protect them by passing such laws as the Preservation of American Antiquities Act of 1906; the National Historic Preservation Act of 1966, amended in 1980; the Archaeological Resource Protection Act of 1979; Executive Order 11539; and the American Indian Religious Freedom Act.

These laws and regulations require Federal agencies to manage the significant cultural resources under their control. To accomplish this, a combination of inventory, protection, and enhancement actions are used. The cultural resource laws and regulations provide specific procedures that must be followed to assure that cultural resource values are considered in any decisionmaking process.

Riparian Vegetation

Riparian vegetation includes any nonaquatic vegetation that directly influences the stream environment. The riparian zone is the area bordering streams, lakes, and wetlands. It is transitional between aquatic and upland zones.

Current Conditions

Riparian plant communities may be dominated by:

1) herbaceous species (mainly rushes, sedges, and grasses);

2) hardwood species (mostly alder, bigleaf maple, willows, Oregon ash, or black cottonwood);

3) coniferous species (western hemlock, Sitka spruce, western redcedar or lodgepole).

There are approximately 775,000 acres of riparian areas within National Forest lands in the Pacific Northwest Region. Riparian areas constitute 1 to 6 percent of the suitable timberlands on East-side Forests, and 3 to 14 percent of the timberlands on West-side Forests.

While riparian areas occupy only a small part of the overall land base in the region, they are a critical source of diversity within the forest ecosystem. They

create distinct habitat zones within the drier surrounding areas.

Interactions

Riparian vegetation provides a source of food, cover, shade, and woody debris for fish and wildlife. Vegetation growing along stream banks helps to stabilize the banks and create habitat for fish. The litter layer serves to filter sediment transported from upland areas by surface erosion. Riparian areas are also highly productive sites for timber and forage.

The Forest Service is mandated to protect riparian areas. No management activities that will cause detrimental changes in water quality, block water courses, or deposit sediment which will seriously and adversely affect water or fish, are permitted within riparian areas.

Fire And Fuels

Fire, and its exclusion, has been a significant factor in the development of plant communities on the National Forests, especially on the east side of the Cascades. All vegetational types have developed subsequent to fires of natural origin. The frequency and intensity of those fires has, to varying degrees,determined the species of trees present on different sites.

Prior to the arrival of European immigrants into the Pacific Northwest area, lightning fires went unchecked and Indians used fire to burn off berryfields and thick underbrush. Some sections of undergrowth were burned every 3 to 5 years. These natural and Indian-caused fires burned at frequent intervals (3-25 years) in the grass and ponderosa pine types, and less frequently (100-300 years) in the mixed conifer stands. Catastrophic fires, such as those that occurred in lodgepole-pine types every 80-120 years, replaced existing stands.

Settlers discouraged the use of fire as a way to manipulate vegetation, seeing it purely as a menace and a threat. The savanna-like pine stands, previously kept clear of underbrush by wildfire or intentional burning, closed in as the result of natural encroachment.

The National Forests have continued to operate under an aggressive fire suppression policy, taking immediate control action on all unplanned ignitions, with the exception of Wildernesses. The Wilderness Act precludes fire suppression in Wildernesses unless there is danger to adjacent resources. This policy of fire suppression has had unexpected side effects. One effect is a decades-long buildup of fuels in some areas. A second effect is that vegetation types have also been changing.

Before 1900, portions of the Forests burned periodically, especially in the more flammable pine stands. Since the inception of fire suppression programs in the early 1900's, the exclusion of fire has changed the environment to one favorable to fire-sensitive fir and associated species. In a study of fire ecology in the Blue Mountains of eastern Oregon, it was noted that the change of vegetational type from ponderosa pine to white fir and Douglas-fir is gradually also changing the Blue Mountain plant community from fire-resistant to fire-susceptible (Hall, 1977).

Fire has played an important role in the evolution of natural ecosystems and is essential to the perpetuation of many plant communities in the Blue Mountains of eastern Oregon and southeast Washington (Hall, 1977). Fire scars indicate that fires of varying intensities occurred on the average of at least once every 10 years prior to fire protection. High intensity conflagration fires allowed plant communities dominated by highly competitive lodgepole pine and western larch to be favored over ponderosa pine, while low intensity surface fires maintained open, park-like stands of mature ponderosa pine and larch by removing competition from less fire-resistant trees and new growth.

Surface fires were a common occurrence in ponderosa pine before the advent of forest management. These fires, occurring at 5- to 25-year intervals at the lower elevations, were often of low intensity and burned accumulations of forest litter and light brush. The result of these fires was a reduction of fuel loadings and the removal of tree species sensitive to fire. The thick-barked pines thrived under this regime of frequent, low-intensity fires which killed off competing vegetation and provided a seed bed for light-demanding pine seedlings. As a result of fire suppression, shade-tolerant species of trees now grow under the pines and may eventually replace the pines in the ponderosa pine zone.

Catastrophic fires with long intervals between them produced the large stands of old-growth Douglas-fir growing on the west side in the western hemlock zone. Fires in the mixed conifer and true fir zones also tend to be intense, stand-replacing burns. Post-fire succession is less well understood in these stands, and a mixture of species is often the result of fires in these zones. Before modern fire protection efforts began, fires occurred infrequently, but often with high intensity. Ecological studies show these stand replacement fires occurred at intervals of 150 years at lower elevations on the west slope of the

Cascades, and at 300 to 1,000 year intervals in higher elevations along the Cascade Crest.

Due to fire suppression and exclusion policies of the past 80 years, the natural ecological cycles involving nutrients, energy, and vegetation dynamics have been altered. Timber harvests have somewhat replaced fire's ecological role through removal and disposal of woody fuels. Grazing also changed vegetation types by removing fire fuels such as grasses, forbs, and succulent brush species. However, neither timber harvest nor grazing duplicates past fire effects. As a result, formerly open pine stands are being replaced by a mosaic of closed canopy, multistoried stands that cover large areas of the forest. These stands are highly flammable and more susceptible to destruction by natural fire, whereas formerly open pine stands were fire maintained (Hall, 1976; Volland and Dell, 1981).

The greatest fire hazard on the forests at present comes from four conditions:

1) areas of fuel created from insect mortality;

2) stands at higher elevations where there is historically a high density of lightning strikes;

3) logging slash, and precommercial thinning slash;

4) areas with a high rate of spread fuels, grass, and shrubs.

Interactions

Many years of effective fire suppression efforts have caused accumulations of needle litter, dead limbs, and dead trees which can lead to high intensity damaging wildfires. Serious outbreaks of mountain pine beetle, western spruce budworm, and Douglas-fir tussock moth have added, or are adding additional fuels.

Natural fuels in the forest are the result of natural processes, but have increased severely in recent years as a result of insect epidemics. The treatment of natural fuels has received very little emphasis resulting in accumulated fuels in many areas beyond the 'natural' condition. The 'unnatural' condition sets the stage for large and destructive wildfires.

Recreation/Public Use

National Forests of the Pacific Northwest have highly diversified natural landscapes, ranging from seacoast to alpine meadows to desert. These offer a correspondingly wide range of recreation opportunities, from clamming to skiing; resorts to wilderness. The Forests, open year-round, receive considerable recreation use, with activities varying according to the season.

There are two Forest Service classifications for recreation: dispersed, and developed.

Dispersed recreation consists of activities that involve little interaction between users. Examples of this include hiking, hunting, and camping in undeveloped or remote locations.

Developed recreation is a concentrated form of recreation involving a range of facilities, from campgrounds to all-season resorts. Examples include family and group campgrounds and picnic areas, winter sports sites, and swimming and boating sites.

The Regional objective is to increase the supply of outdoor recreation opportunities and services through programs that emphasize dispersed recreation. Current use levels of developed or concentrated site recreation will be maintained.

Use of the Pacific Northwest Region's (slightly over 1,900) developed recreation sites currently equals over 13 million Recreation Visitor Days (RVD's). A Recreation Visitor Day is defined as being equal to 12 hours spent by a visitor. This figure includes RVD's at Forest Service operations; permittee operations; and privately-owned sites within National Forest boundaries.

Dispersed recreation accounts for over 18 million Recreation Visitor Days on approximately 1,700 dispersed recreation areas.

Interactions

Forest pests have a potential to greatly influence the recreational use that an area receives. In particular, western spruce budworm and mountain pine beetle can produce dramatic changes to the local environment, reducing outdoor recreation enjoyment.

Social And Economic Conditions

The area of influence for the purposes of this report--the people and communities most directly influenced by National Forest management activities and outputs of the Pacific Northwest Region--comprises the States of Oregon and Washington. A description of the social and economic conditions of these two States, and their principal ties to National Forests in the Region follows:

The Region, West and East

Oregon and Washington contain a great variety of land forms that reflect the results of water, volcanic, and glacial events. The major geological feature is the Cascade Mountain Range, which parallels the Pacific coastline about 100 miles inland. This rugged range divides the region into two distinct zones, west and east. Climate, vegetation, the economy, and population patterns are different on the west and east sides of the Cascades.

The West-side

The western part of the region has 5.7 million people. It contains the majority of the population of the two States. Eighty-seven percent of Oregon's population and 69 percent of Washington's population reside west of the Cascades. Population centers are concentrated along the Puget Sound in Washington, and the Willamette Valley in Oregon.

They are linked by north-south Interstate Highway 5, and by the Southern Pacific, Burlington Northern, and Union Pacific railroads. Major ports on Puget Sound and the Columbia River provide trade links to the Pacific Ocean nations.

The economy in the western portion of the region is relatively diversified; more so in Washington than in Oregon. Aircraft manufacturing, shipbuilding, forest products industries, major financial centers, service and trade centers, educational centers, government, commercial fishing, agriculture, the livestock industry, recreation facilities, and mining all contribute to the economic picture.

The East-side

The eastern part of the region covers two-thirds of the land area of Oregon and Washington. It contains a smaller proportion of the population: about 13 percent of Oregonians and 31 percent of Washingtonians live east of the Cascade Mountains. Oregon has no metropolitan areas on the East-side; Washington has Yakima, The Tri-Cities, and Spokane.

Major transportation linkages include Interstate Highway 90 and the Burlington Northern Railroad (providing east-west transportation), supplemented by the Columbia River corridor, with rail, Interstate Highway 84, and barge transportation. The remaining East-side area is not as well-served.

The economy of the eastern portion of the region depends more on agriculture, forest products industries, and the livestock industry than does the western portion. The relative dependence on these sectors has not been balanced by growth in other major employment sectors, except for some localized growth in recreation and service industries. The East-side has fewer opportunities for employment. The cities and towns reflect a rural-based economy with little diversification.

The Pacific Northwest is a region in transition. The region is moving toward a more diversified economic base. The traditional employment sectors simply do not have the same labor requirements as they did in the past. Many felt that the natural wonders of the area would be sufficient to guarantee its growth. Actually, growth has declined markedly, as shown in Table III-IV.

Population

The population of Oregon and Washington was 6,763,312 in 1980, an increase of over 2 million people in two decades, equaling a 1.9 percent annual growth rate. Since 1980, the annual rate of growth has slowed to 0.8 percent, with the majority occurring in Washington.

Urban/Rural Population

There are significant differences between Washington and Oregon in the distribution of population. Washington contains 61 percent of the region's population; the vast majority of these residents live in urban areas. There are five metropolitan areas in western Washington--Bellingham, Seattle-Everett, Bremerton, Tacoma, and Olympia. Three more are east of the Cascades--Yakima, Spokane, and Richland-Kennewick-Pasco.

Oregon's population, 39 percent of the region's total, is also primarily urban. The State has four metropolitan areas, all on the west side of the Cascades--Portland (which includes Vancouver, Washington), Salem, Eugene-Springfield, and Medford. Table III-V shows the 1980 distribution of population between urban and rural areas.

Minorities

Racial and cultural minorities are a small segment of the two States' population. In 1980, Blacks comprised 2 percent of the population, American Indians 1 percent, Hispanics 2 percent, and Asians 2 percent. Blacks in the region are predominately urban in their residence, while Native Americans and Hispanics are more rural than the overall population.

There are over 20 Indian Reservations in the two States. Many are adjacent to National Forests, and Native Americans have significant concerns about Forest resources and management.

Age, Sex, and Labor Force Participation

After 1970, the age composition of the region's population shifted, and by 1980, a larger proportion of the population was of working age. A significant increase, from 43 percent to 52 percent, in the number of women in the labor force occurred for women aged 16 and over. As the age structure of the region continues to shift, the size and other characteristics of the labor force will be impacted (Bonneville Power Administration, 1982).

The Economy

The Pacific Northwest has a history of dependence on resource-based industries. Diversification, an ongoing process, is more advanced in Washington than in Oregon. The Pacific Northwest Region is noted for its environmental quality, is located favorably for foreign trade, and has a well-educated work force.

The major centers of growth and diversification are in the Puget Sound, Spokane, and Willamette Valley metropolitan areas. While employment in agriculture, and lumber and wood products has declined over time, the natural resources of the region will continue to play an important role in its economic base. Table III-VI summarizes recent area employment.

Data from the two States are not necessarily comparable due to differences in definitions. Data shown represent covered employment, and thus are exclusive of proprietors, family-member work on farms, and others.

Lifestyles, Attitudes, Beliefs, and Values

Many people find the Pacific Northwest an appealing place to live. To some extent, this has been translated into the location of new enterprises in the area. As much as anything else, though, the 1980's are likely to be remembered as the time when the Pacific Northwest realized that its continued growth would not come about without effort--that it would have to work to attract suitable employers, and that other locations in the Nation were also viewed as being desirable places to live and work.

Certainly, there is no one regional lifestyle or set of attitudes, beliefs, and values. Such generalizations are inaccurate today, just as they were in the past. Continuing improvements in technology have helped shift the metropolitan economies from their historical resource bases to more diversified bases. Strong environmental concerns have developed which are not restricted geographically or by occupation.

Because the economies of the rural communities are more typically associated with commodity production, residents of those areas are frequently perceived as being more likely to favor higher production levels and heightened development. Residents of metropolitan areas whose livelihoods are not directly or noticeably linked to the extraction of natural resources are more commonly viewed as favoring environmental concerns. The relationship is not that cut-and-dried, of course, as is demonstrated, for example, by the 1986 public opinion survey conducted by the Oregon State Board of Forestry.

Environmentalists live in rural areas as well as in metropolitan areas, just as do those who favor development of the resource base. There is no simple line of demarcation between these camps. Environmentalists are concerned about their neighbors' jobs, and millworkers are frequently among the first to note their concern for the environment.

The economy of the Pacific Northwest is slowly, but surely, moving toward more diversity, away from its historic dependence on the extraction of natural resources, and the initial manufacturing of them. With that change comes a greater regional resilience to economic cycles, and an increasingly important role for National Forests as places of recreation, natural diversity, and high environmental quality. Within that context of change will be additional changes stemming from the alternative ways of managing vegetation proposed in this EIS.

Interactions

Forest pests can have dramatic impacts on the social and economic components of the environment. Major infestations such as the current western spruce budworm outbreak, recent episodes with mountain pine beetle, and the gypsy moth outbreak all represent threats to local communities and to the Region. The threats are often times, expressed in terms of lost jobs due to an impending scarcity of resources.

Land Uses

Landownership patterns within the Pacific Northwest Region of the Forest Service are highly complex around and within National Forest boundaries. Many of the private holdings are managed for timber production by private industrial owners. State and Federal agencies (the Oregon Department of Forestry, Washington Department of Natural Resources, and the USDI Bureau of Land Management, for example) also manage large tracts of land within and adjacent to the boundaries of the Region.

The Region is comprised of 24,545,814 acres of National Forest system land (1986 figures). This land is contained within 23,894 miles of boundary. Also contained within this boundary are 2,765,197 acres of lands in other ownerships.

Interactions

Smaller landowners use their land for a variety of purposes; recreational residences, organizational uses, farms, small woodlots, and small businesses, to name a few. Generally, large industrial landowners tend to emphasize uses of the environment different than those of smaller landowners. For example, large, private timber holdings are usually intensively managed for timber production. Less emphasis may be given to other resource values on these lands. The checkerboard pattern of landownership, along with the diversity of land uses, is a complicating factor in the management of forest pests.

Public Health

Populations

The states of Oregon and Washington had a combined population of approximately 7 million people as of 1984. Washington's recorded population was 4.35 million people; Oregon's was 2.67 million. People in the region enjoy above-average good health, compared to the total U.S. population.

The overall 1982 death rate per 100,000 in Washington was 755.4; in Oregon, 810.1; and in the U.S., 852.0. The figures for cancer deaths were 171.0, 179.4, and 187.2, respectively. In contrast, the death rates from accidents were 41.4 in Washington, 41.6 in Oregon, and 40.6 nationally.

The Forest Service estimates that 100,000 people live within one mile of the National Forests (including 30,000 who live within a quarter-mile). The Forest Service reports a trend of increasing numbers of residents living near National Forests.

This increasing proximity of people living near lands managed by the Forest Service has resulted in increasing public concern with environmental issues such as air and water quality and public health. In particular, concerns have been raised about use of pesticides.

Backgound Health Risks in the Pacific Northwest

This section discusses background human health risks of injuries. cancer, and other diseases for people living in the Pacific Northwest. As is true for the U.S. population as a whole, people in the Pacific Northwest are exposed to risks from outomobile accidents; contaminants in the air, water, and soil; chemicals in the diet; and many other injuries and diseases. Occupational risks may be different than those that face thye general public, depending upon the work environment. Some of these risks can be quantified, while lack of data allows only a qualitative description of others. Also, in some subject areas, information is available for the United States as a whole, but not specifically for the Pacific Northwest. In such cases, it is assumed that the U.S. data apply to conditions in the Pacific Northwest

Sources of information for this section include detailed discussions of the 10 leading work-related diseases by the Centers for Diseased Control; injuries, as determined by the National Institute for Occupational Safety and Health (NIOSH) Centers for Disease Control 1987; summariesd of vital statistics (births and deaths) for Washington and Oregon; the National Research Council's "Regulating Pesticides in Food--the Delaney Paradox," and "Injury in America," and Calabrese and Dorsey's "Healthy Living in an Unhealthy World." Except for certain infectious, notifiable diseases, there is little statistical information on nonfatal conditions, including cancers that either are cured or are not the primary cause of mortality.

Risks from Injuries

Injury Incidence. Seventy million Americans incur nonfatal injuries every year. Among those less than 45 years old, injuries are the leading cause of hospitalization (National Research Council, 1985).

NIOSH estimates that about 10 million traumatic injuries occur annually to people at work in the United States (Centers for Disease Control 1987). Several chronic injuries also are directly linked to the type of work done. For example, vibration syndrome affects up to 90 percent of workers using chippers, grinder,

chainsaws, jackhammers, or other handheld power tools, causing blanching and reduced sensitivity in the fingers (Centers for Disease Control, 1981). Noise-induced hearing loss affects 17 percent of U.S. production workers who are exposed to noise levels of 80 decibels or more on a daily basis (Centers for Disease Control, 1987).

Injury Mortality. Approximately 140,000 Americans die from injuries annually. Of the 94,072 deaths from unintentional injury in 1982, 47.5 percent were due to motor vehicle accidents, 12.8 percent to falls and jumps, 6.8 percent to drowning, 3.7 percent to poisoning, and the other 29.2 percent to a wide range of causes (National Research Council, 1985). Injuries are the major cause of death among young adults and children. From the ages of 15 to 24, injuries cause almost 80 percent of the fatalities (National Research Council, 1985)

Injuries cause about 10,000 occupational fatalities per year (Centers for Disease Control, 1987). Some of the causes include highway motor vehicle accidents (34.1 percent in 1980 to 81), falls (12.5 percent), industrial vehicle or equipment accidents (11.4 percent), and fires (3.4 percent) (Centers for Disease Control, 1987). Workers in the mining and quarrying industry had the highest rate of traumatic deaths, at 55 per 100,000 workers. Agriculture had a rate of 52 deaths per 100,000 workers, while trade had only 5 deaths per 100,000 workers (Centers for Disease Control, 1987).

In Washington, 1985 data show that out of 34,475 total deaths, 830, or less than 3 percent, were accidental, nonvehicular fatalities. Of these, 252 were from falls, 104 from poisoning, 98 from drowning, 69 from fire, at least 64 from mechanical trauma, and the rest from various other types of accidents. Over one-half occurred in the place of residence (Washington State Department of Social & Health Services, 1986).

Table III-VII indicates that deaths from falls, fires, and accidental poisoning are relatively rare in both States. Forestry-related deaths from any of these causes are exceptionally rare in either State.

Risk of Cancer

Cancer Incidence. Nationwide, the chance of developing some form of cancer during one's lifetime is about 1 in 4 (Calabrese and Dorsey, 1984 and National Research Council, 1982). The causes of cancer development are many, including occupational exposure to carcinogens, environmental contaminants, and substances in food. In the United States, one-third of all cancers have been attributed to tobacco smoking (Chu and Kamely, 1988). It is estimated that work-related cancers account for anywhere from 4 to 20 percent of all malignancies (Center for Disease Control, 1987); however, it is difficult to quantify the information because of such factors as long intervals of time between exposure and diagnosis, personal behavior patterns, job changes, exposure to other carcinogens, and difficulties in documentation.

The diet plays a significant role in cancer incidence. Different estimates hold diet responsible for anywhere from 30 to 90 percent of all cancer in humans (National Research Council, 1982). Pesticide residues in food contribute to the total cancer risk encountered. Based on the review of oncogenic pesticides in food by the National Research Council, overall risks of cancer are increased over the background cancer risk of 0.25 (1 in 4 lifetime risk) by 0.001 in the United States as a whole. Most of this increased risk is attributable to a single group of compounds, the fungicides, with herbicides contributing 27.1 percent (of the 0.001 increased risk), which is equal to 0.000271 increased risk. Virtually all herbicide risk is due to a single compound, linuron, which makes up 96.1 percent of the herbicide risk and 26 percent of the total risk from pesticide residues in food (National Research Council, 1987).

Cancer Mortality. Based on the data in Table III-VII, cancer accounted for 22.6 percent of all 1986 Oregon fatalities, and 23.2 percent of 1985 Washington fatalities. These figures are reflective of national cancer mortality figures, with cancer accounting for 22.1 percent of 1985 deaths in the United States (U.S. Bureau of the Census, 1988).

Risk of Diseases other than Cancer

Disease Incidence. According to the Centers for Disease Control, clear causal links have been established between certain occupations and specific illnesses. For example, asbestosis among insulation and shipyard workers has been linked to their exposure to asbestos, which pneumoconiosis among coal miners has been linked to the inhalation of coal dust. Occupational exposures to some metals, dusts, and trace elements, as well as carbon monoxide, carbon disulfide, halogenated hydrocarbons, nitroglycerin, and nitrates, can result in an increased incidence of cardiovascular disease. Occupational exposure to lead and ionizing radiation may lead to reduced male fertility. Female laboratory and chemical workers show a higher rate of miscarriage than the general population. Neurotoxic disorders can arise from exposure to a wide range of chemicals, including such commonly used pesticides as 2,4-D, methyl bromide, and organochlorine insecticides. Dermatologic conditions, such as contact dermatitis, infection, trauma, cancer, vitiligo, urticaria, and

chloracne, have a high rate of occurrence in the agricultural, forestry, and fishing industries, with 2,233 reported cases in 1984, and an incidence rate of 28.5 per 10,000 workers.

Disease Mortality. The mortality rates for Oregon (1986) and Washington (1985) are listed in Table III-VII. The leading causes of death are listed, along with numbers of deaths and rates per 100,000. The Oregon death rate slightly exceeds the national average of 870 per 100,000. The Washington rate is well below the national average. Heart disease is the principal cause of death in both States. Other significant disease-related deaths include cerebrovascular disease and respiratory disorders.

Table III-I

Timber Productivity on Available Commercial Forest Lands in the Pacific Northwest Region (Cubic Feet per Acre per Year)

	Productivity Class				
	120+	85-119	50-84	20-49	Total
Coastal and Western Cascades subregion					
Thousand Acres	2,825	1,552	1,991	290	6,658
Percent	43	23	30	4	100
East-side and Transition subregion					
Thousand Acres	655	2,148	5,399	1,660	9,862
Percent	7	22	55	16	100
Total Region					
Thousand Acres	3,480	3,700	7,390	1,950	16,520
Percent	21	22	45	12	100

Source: Regional Guide for the Pacific Northwest Region, 1984, USDA Forest Service.

Table III-II

Standing Softwood Volumes--based on International 1/4-inch Scale--on Commercial Forest Lands of the Pacific Northwest Region

	Million Board Feet	Percent
Coastal and Western Cascades subregion	270,508	70
East-side and Transition subregion	115,944	30
Total	386,452	100

Source: Regional Guide for the Pacific Northwest Region, 1984, USDA Forest Service.

Table III-III

Threatened and Endangered Wildlife Species

Gray wolf *Canis lupus*	E
Grizzly bear *Ursus arctos*	T
Woodland caribou *Rangifer tarandus californiana*	E
Brown pelican *Pelecanus occidentalis*	E
Northern bald eagle *Haliaetus leucocephalus*	T
American peregrine falcon *Falco peregrinus anatum*	E

T = Threatened E = Endangered

Table III-IV

Population Size and Growth Rates

Oregon and Washington

	1960	1980	1986	Average Annual Rate of Increase (Percent) 1960–1980	1980–1986
Washington	2,853,214	4,130,163	4,419,700	1.9	1.1
Oregon	1,768,687	2,633,149	2,659,500	2.0	0.2
Total	4,621,901	6,763,312	7,079,200	1.9	0.8

Source of 1960 and 1980 Data: 1980 Census. 1986 Oregon data calculated from Table 3 of Population Estimates of Oregon, Counties and Cities, July 1, 1986, published by the Center for Population Research and Census, School of Urban and Public Affairs, Portland State University. 1986 Washington data calculated from Table 9 of 1986 Population Trends for Washington State, August, 1986, published by the Office of Financial Management of the State of Washington.

Table III-V

Population Distribution--Urban and Rural, 1980

	Urban	Rural
Washington	74%	26%
Oregon	68%	32%

Table III-VI

Employment in Oregon and Washington in the Mid-1980's

(Thousands of Jobs)

	Oregon	Washington	Total
Total (100%)	1,210	1,617	2,827
Lumber & Wood Products	64 (5.3%)	41 (2.5%)	105 (3.7%)
Paper & Allied Products	9 (0.7%)	16 (0.9%)	25 (0.8%)
Agriculture, Forestry, and Fishing	23 (1.9%)	44 (2.7%)	67 (2.4%)

Oregon data for the above table are for 1985. They were taken from page 2 of **Oregon Industrial Outlook**, published by the Employment Division, Department of Human Resources, State of Oregon (RS PUB 78 (5-86)). Washington data for the above table are for 1984. They are taken from page 113 of **Employment and Payrolls in Washington State by County and Industry**, Fourth Quarter 1984, No. 153, January 1986.

Table III-VII

Mortality Rates and Causes of Death in the Pacific Northwest

Cause of Death	Number of Deaths (Mortality Rate) Oregon[1/]	Washington[2/]
All causes	23,328 (877.2)[3/]	34,475 (786.4)
Heart disease (rate)	7,788 (292.8)	11,713 (267.2)
Cancer (rate)	5,272 (198.2)	8,007 (182.6)
Cerebrovascular disease	1,926 (72.4)	2,709 (61.S)
Accidents	1,184 (44.5)	1,635 (37.3)
Motor vehicle	638 (24.0)	805 (1S.4)
Falls	ND	252 (5.7)
Fire	ND	69 (1.6)
Poisoning	ND	104 (2.4)
Respiratory disease	1,090 (41.0)	1,951 (44.5)
All other causes	6,068 (228.2)	8,460 (193.0)

Sources: Oregon Department of Human Resources, 1987; Washington State Department of Social & Health Services, 1985

[1/] 1986.

[2/] 1985.

[3/] All numbers in parentheses are rates per 100,000.

ND: No data.

Chapter 4: Environmental Consequences

Moth (adult)

CHAPTER IV. ENVIRONMENTAL CONSEQUENCES

Introduction

This chapter discusses the environmental consequences that would occur if the alternatives presented in this EIS were implemented. This discussion provides information that is a basis for the comparison of alternatives presented in Chapter II.

In June and July of 1988, the Interdisciplinary Team utilized an open public process to identify significant issues. These issues were used in the formulation of alternatives and consideration of the effects of those alternatives.

Three of the eight issues identified concern for potentially significant adverse impacts on the human environment. The potential impacts are in the areas of human health, social and economic effects, and environmental effects. See Chapter I for a discussion of the issues and scoping process.

Background

Estimating Environmental Consequences

Environmental consequences (or effects) occur when ecosystems are changed--whether through management action or inaction. Under each action alternative, the western spruce budworm infestation would be managed utilizing either a biological or chemical method, or both. This chapter presents the environmental consequences of the no action and action management alternatives.

The core of the chapter is organized by environmental components, such as soils, wildlife, and social and economic effects. Next, direct environmental effects are discussed, along with the reasons they occur. Changes in one part of the environment often lead to changes in other parts. These indirect effects are also presented.

Standards and guidelines for western spruce budworm control were developed to mitigate impacts caused by implementation of the action alternatives. In estimating environmental effects, these mitigating measures are assumed to be in place and effective.

Site-specific Environmental Effects

The western spruce budworm infestation management program involves site-specific projects in the Region over a period of several years. The environmental consequences of each will be different, depending upon the characteristics of that particular project site.

In addition to this EIS, if an action alternative is selected, project-specific environmental analysis will be required before project implementation. This project-specific environmental analysis would be conducted as each treatment year is considered. The analysis would serve as a analysis tool for specific projects, as well as involving the public, on a yearly basis, in location and treatment decisions. If the no action alternative is selected, monitoring of the current outbreak will continue.

Regional Environmental Effects

The portion of the Pacific Northwest Region which supports western spruce budworm habitat is extensive. The current infestation is located primarily in East-side Forests, but has spread across the Cascades into portions of West-side Forests. The ID Team was faced with the problem of estimating the environmental effects of a treatment program on these areas.

Resource managers and specialists on individual National Forests are familiar with the extent and nature of the western spruce budworm infestation on each respective Forest. Whenever possible, the team consulted with these people. This information, combined with the ID Team's knowledge of ecological processes, research literature, and Forest management experience, was the basis for estimating the environmental impacts of the alternatives.

Much of the material on human health effects was compiled, analyzed, and reviewed by Labatt Anderson Incorporated, a private contractor in Arlington,

Virginia, that specializes in conducting quantitative risk assessments.

Water Quality/Quantity

It has been known since the early 1900's that the removal of forest vegetation increases streamflow. This is primarily a result of transpiration and interception. In addition, an increase in soil water storage can be anticipated due to a decrease in transpiration. These effects are most pronounced immediately after vegetative removal and decrease as the vegetation recovers or the area is reforested and matures. The magnitude of the increase or decrease is a function of climate, topography, percentage of vegetation removed, soil water storage and other environmental factors (Hibbert, 1967). There may, or may not, be an increase in runoff dependent upon these factors.

Silvey (1973) indicated about a third of the anticipated water yield increases resulting from timber harvest in the snow zone on the Nez Perce National Forest were attributable to snow redistribution. Since these increases resulted from a disruption of the shear plane at canopy level, caused by the removal of trees, no significant impact should be produced by a budworm infestation. Increases in snow accumulation due to reduced snow interception would still be expected.

Most research related to hydrologic effects of insect infestation has dealt with bark beetles. A severe outbreak of Engelmann spruce beetle occurred in the White River National Forest between 1939 and 1946. Up to 80 percent of the Engelmann spruce and lodgepole pine on 30 percent of the gauged watersheds on the White River drainage were killed. Helvey (1978) indicated that most of the Engelmann spruce and lodgepole pine in a 226- square-mile area were killed. Even after 25 years, the runoff was 10 percent above preinfestation-projected levels (Bethlahmy, 1975).

Potts (1984) analyzed a pine bark beetle outbreak on a subdrainage of the Madison River in southwest Montana. Thirty-five percent of the timber on the 51.5-square-mile Jack Creek watershed was killed. Gauging records indicated a 15-percent post-epidemic increase in flow with a 2- to 3-week advance in the hydrograph (spring runoff and peak flow). There was a 10-percent increase in base flow. No significant increase was observed in peak flow.

Helvey (1978) studied the effects of Douglas-fir tussock moth defoliation on streamflow in three drainages in the Blue Mountains of northeast Oregon and southeast Washington. Because the tussock moth and budworm are both defoliators, these results most closely approximate the impacts associated with a spruce budworm infestation. Helvey assumed top-killing removed one-half the transpiring surfaces, and heavy mortality removed all surfaces. No change in streamflow was detected in the lightly defoliated basins (13 percent and 16 percent), and no effect on peak flow was detected on any of the drainages. The Umatilla Basin, which was 25 percent defoliated, showed a statistically significant increase on the third year only. Helvey postulated that if this increase during the third year was due to defoliation, the return to nonsignificant flows the following year was possibly due to greenup (vegetative recovery).

A study of tussock moth defoliation on the Umatilla National Forest by Hicks (1977), found no significant difference in water quality between affected and unaffected watersheds.

In a world-wide literature review, Hibbert (1965) determined that at least 20 percent of a basin must be deforested before a significant increase in runoff can be detected. This is consistent with the results published by Potts (1984) and Helvey (1978). Hibbert attributed this to increased water use by remaining trees and vegetation, with experimental error associated with base-line data. Increases in streamflow are normally derived from U.S. Geological Survey (USGS) gauging records. Records are rated as "good" by USGS when 95 percent of the daily discharge values are within 10 percent of the true value. Therefore, an increase of less than 10 percent cannot be detected.

Silvey (1973) developed the concept of equivalent clearcut area (ECA) to define the total area within a drainage in a clearcut condition. This includes the sum of the area in clearcuts, plus an ECA for roads, partial-cuts, and selective-cut units. Figure IV-1 provides an estimate of the ECA in partial-cut areas. This graph would represent the impact of an infestation in a mixed stand with a large component of resistant species. Much of this buffering effect is the result of higher water use by the remaining, nontreatment trees. In a stand composed almost exclusively of nonresistant species, and without a vegetative ground cover, this buffering effect would not be significant. Therefore, the level at which defoliation produces a significant increase in flow should be somewhat higher than 20 percent.

In the Pacific Northwest, vegetation removal, while increasing annual flow, does not appear to significantly increase peak flow discharge rates (Harr, 1976). However, in the northern Rocky Mountains where annual runoff is primarily dependent upon snowmelt, studies appear to indicate that timber

harvest can increase peak flow (Bethlahmy, 1973; Galbraith, 1973). Based upon procedures contained in Forest Hydrology, Part II (USDA Forest Service, Region 6), it is possible to harvest timber without increasing peak flow by distributing units to maximize snowmelt timing. The absence of any significant increase in peak flows after insect infestation tends to confirm that distribution of a treatment throughout a basin should not increase peak flow.

The channel maintenance flow concept used in Forest Service Handbook (FSH) 2509.17 to quantify flows needed for self-maintenance of stream channels, assumes stream channels are the result of a range of frequently occurring flows. Sediment yield is a function of the frequency and duration of flows above mean annual discharge (Rosgen, 1986). Thus, increases in the rising and falling arm of the hydrograph, as well as peak flow, have an effect on sediment loading and bank erosion.

Spruce budworm defoliation in initial stages only affects the current year's growth requiring 4 to 5 years to produce severe defoliation. The tussock moth, on the other hand, attacks all foliage, producing severe defoliation by the second year. The longer time required for severe defoliation to occur in budworm infestations should allow unaffected vegetation to increase to a density which would use a larger portion of the available water. This, coupled with lower mortality resulting from a budworm infestation, would produce a smaller increase in flow than a comparable tussock moth infestation.

Based upon the maximum anticipated basin defoliation rates projected for a spruce budworm infestation, and the similarity between tussock moth and spruce budworm infestations, no significant increase in streamflows or peak discharges should result solely from spruce budworm impacts. However, significant increases in annual streamflow could result from the cumulative impacts of a severe budworm defoliation and management activities. In streams incised in alluvium which can be moved by flows at or below bank full, increases in annual flow resulting from cumulative effects could result in increased sediment loading and bank erosion. Areas of concern would include streams that are actively aggregating or degrading, and streams with high livestock impacts.

Alternative A - No Action

Alternative A, the No-action Alternative, should have minimal impacts on water quality and quantity. Maximum total defoliation should be no greater than 25 percent with less than 3 percent of this in mortality. No significant increase in annual streamflow or peak discharge is anticipated. Defoliation and mortality could slightly increase water temperature in some reaches, but this should have a small spatial impact and should not be significant. In watersheds with extensive ongoing management activities, the cumulative impacts of these activities and budworm defoliation could produce a significant increase in annual streamflow. While no additional increase in peak flow should occur, the increase in annual flow could degrade water quality. These impacts could delay the implementation of additional activities until either the budworm epidemic had subsided or vegetation on harvested units had sufficiently recovered to lower the increased runoff or sediment load to acceptable levels.

Alternatives B, C, and D

Implementation of Alternatives B, C, and D would reduce defoliation and eliminate the slight impacts described in the No-action Alternative. Also, that portion of a cumulative impact attributable to defoliation would be removed.

Mitigating Measures

Aerial insecticide application near streams and open water is controlled by State law. In Oregon, State regulatory agencies have agreed that *B.t.* may be aerially applied parallel to and up to the edges of streams and open water. A variance must be obtained from the Washington State Department of Ecology to apply *B.t* up to the edges of streams in that State.

A buffer zone will be left adjacent to streams, lakes, wetlands, and other waterways when applying carbaryl. This buffer strip must be at least one swath wide.

The following measures will be used to minimize the probability of unintentional adverse effects on water-related resources and nontarget organisms from spills or application errors:

Aircraft spray equipment calibration testing over wetlands or floodplains will be prohibited.

A pilot car will be required during transportation of insecticides or fuel on roads within municipal watersheds.

Helispots will not be located in or adjacent to meadowlands or floodplains.

Wetlands, including lakes and ponds, which are large enough to identify from the air, will not be oversprayed with insecticides. There may be relatively small wet areas that, because of the tree canopy cover, cannot be identified from the air which will be unavoidably but inadvertently sprayed.

Geology

Geology interacts, either directly or indirectly, with all other environmental factors. Soil development, plant composition, and growth rates of host species can be directly related to the local geology. Soil moisture retention is indirectly related to the geologic material and how it weathers. However, the implementation of alternatives and the application of methods considered in this EIS are not expected to affect the geology. There would be no cumulative geological effects from inplementation of any of the alternatives.

Soils

Alternative A - No Action

Alternative A would have no effect on soil properties. Loss of vegetation would not be great enough to cause erosion. Some localized soil compaction might occur due to salvage of dead trees. There would be no cumulative effects on the soil resource due to implementation of this alternative.

Alternatives B, C, and D

Implementation of the action alternatives would have a minor effect on soil chemistry and microbiology. In these alternatives, carbaryl and/or *B.t.* would be applied aerially. There would be no mechanical effect upon soil structure. The major consideration would be persistence of these insecticides in the soil.

This persistence depends upon chemical properties, climatic factors, soil properties, and initial rate of application. Many soil microorganisms are capable of breaking down these insecticides.

None of the action alternatives would produce any short- or long-term cumulative effects, since such small amounts of chemicals would reach the soil.

Alternatives C and D

Carbaryl has a soil half-life of 14 days (Environmental Protection Agency 1986b). Degradation of carbaryl in the soil results primarily from the metabolic activity of microorganisms (Heywood, 1975). A half-life in soil of 8 days has been reported by Johnson and Stansbury (1965). Only 6 percent of applied carbaryl could be recovered from treated soil 28 days after application. In addition, less than 3 percent remained as water-soluble metabolites. Degradation of carbaryl by soil microorganisms produces several toxic reaction intermediates, including 1-napthol and hydroxy-methylcarbamates. Heywood (1975) also found that 68 percent of hydroxylated metabolites were broken down in soil after 9 weeks. Soils placed in storage were found to degrade a variety of carbamate insecticides at a lower rate. Carbaryl has been found to be degraded by the soil fungus *Aspergillus terreus* (Liu and Bollag, 1971). Carbaryl degraded with a half-life of 6 days in *A. terreus* cultures, and 1-napthol was also metabolized into unidentified degradation products. Soil mite populations are unaffected by carbaryl (Moulding, 1972). Catalysis of carbaryl degradation by soil minerals is not well understood, but it is clear that the degradation of carbaryl in soils can be attributed more to biological activity than to soil mineral composition (Heywood, 1975).

Alternatives B and D

Persistence of *B.t.* in soils was reviewed by Forsvbery et al. (1976). *B.t.* formulations appear to be moderately persistent.

Ignoffo and Graham (1967) reported a 90-percent reduction in spore count after 4 months for Bakthan L-69 applied to soil which was exposed to the atmosphere and to rainfall. Saleh et al. (1970) treated various soils with Thuricide T and with Biotrol BTB wettable powder. They reported recovery of 7,800 to 170,000 spores per gram of soil from silty clay and from two silt loams up to 40 days after application. In laboratory soil studies, these authors reported that *B.t.* spores germinated and exhibited population growth in organically amended soils, but in low pH (5.2) soil that has not been organically amended, the spores germinated while the vegetative cells died.

Climate

Climate interacts with all other environmental components directly and indirectly. However, western spruce budworm management activities are not expected to have significant or cumulative effects on the regional climate. Climate plays a major role in the suitability of host species for major western spruce budworm epidemics.

Stress created in the host species by the current drought has intensified the present epidemic. Stressed trees are more susceptible to attack by insects or disease, much the same as humans. Lack of adequate precipitation has been one of several factors contributing to the current situation.

Vegetation (Unmanaged Stands)

Alternative A - No Action

The No-action Alternative, over time, would open pockets in the tree canopy due to mortality. These pockets would receive more sunshine and could allow less shade tolerant and more resistant species, such as the pine species, to re-enter the stands. The stand structure would slowly change to include a mixture of species which are less susceptible to attack by spruce budworm. The cumulative effect of this alternative would be a gradual change of stand structure over time.

Alternatives B, C, and D

The action alternatives would tend to keep stands and attendant plant communities in their present state of development. The stands would continue to be comprised of susceptible species such as true firs and Douglas-fir. As the stands are brought into a managed condition through implementation of Forest Plans, stand compositions will change to a mixture of species which are less susceptible. There are no cumulative effects on vegetation due to any of the action alternatives.

Timber (Managed Stands)

Timber stands affected by the current spruce budworm outbreak suffer various types and degrees of damage to wood fiber production. The most measurable result is growth loss. This loss of wood fiber production is a result of spruce budworm-caused tree mortality, top-kill, and deformity. Reduced seed production may also be attributed to spruce budworm damage. All of these symptoms may occur as high-magnitude effects on relatively small areas. These small areas are usually irregularly distributed through the general zone of infestation and cause considerable concern for local land managers.

Potential for Growth Loss

Alternative A - No Action

A major impact of budworm defoliation on a timber stand is growth loss. By feeding on tree foliage, budworm larvae reduce the host tree's vigor, resulting in reduced height and diameter growth rates. The net effect on the growth rate of a stand of trees depends upon several factors, including species composition, tree size, tree age, stocking levels, and site quality. Stands with a large proportion of host tree species are more prone to sustaining growth loss than stands composed of a mixture of species, due to a greater proportion of the stand being affected. Grand fir is known to suffer more damage than Douglas-fir (Carolin, 1975). Numerous studies have revealed that radial growth reduction lags behind foliage removal by 1 to 3 years (Alfaro et al., 1982; Crimp, 1982). Similarly, growth recovery lags behind cessation of defoliation.

Radial growth loss is most often expressed relative to preoutbreak growth rates. Shepherd et al. (1977) observed an annual increment reduction of 40 to 80 percent in Douglas-fir. Gregg et al. (1979) found the reduction in mean annual increment relative to predicted growth averaged 12 percent in Douglas-fir, and 27 percent in true fir, after 5 years of repeated defoliation.

Height growth is also affected by budworm defoliation. Severely defoliated Douglas-fir in British Columbia produced no height growth for a period of 10 years (Shepherd et al., 1977). In Washington, where lighter defoliation occurred for a shorter time period, height growth loss was compensated by a lateral shoot quickly achieving dominance. The proportional loss of height growth was similar to, or less than, diameter growth (Scott and Nichols, 1983).

The combined loss of radial and height increment results in stand volume loss over time. Stand volume losses are usually calculated as the difference between observed volume and a predicted volume. Harvey reports average stand volume in north-central Washington after a 10-year outbreak as a 2.9 percent loss of predicted growth. In Idaho, stand volume losses were calculated as 1 percent less than predicted growth (Bousfield et al., 1975).

In young stands with apparent top-kill or mortality, precommercial thinning may be postponed until the outbreak subsides to assure that severely damaged trees are removed and the best trees are retained for future growth. Rescheduling this thinning defers the benefits of release in the stand and probably will lengthen the rotation age.

Stand volume losses can be compensated for by increases in radial growth of nonhost species, such as pine, growing within the defoliated stand. Carlson and McCaughey (1982) have shown an apparent radial growth acceleration of pine growing in defoliated stands in western Montana. This effect has also been demonstrated in Douglas-fir tussock moth infestations by Brubaker (1978) and Wickman (1978).

Under the No-action Alternative, the maximum amount of budworm-caused growth loss would

continue until the population collapsed due to natural regulating factors, or until a subsequent analysis determined that suppression measures were needed. In the long term, as the host trees are replaced by more resistant species, growth loss due to the infestation would become less.

Cumulative effects on timber would be a continuing and expanding loss of fiber production until the outbreak cycle collapsed or stand replacement occurred.

Alternatives B, C, and D

Projections show that implementation of these alternatives would result in a level of budworm population control that would avert most additional loss of wood fiber production due to the current outbreak. Because of the variablity in site productivity in the region, actual projected increases of fiber production over the No-action Alternative would have to be estimated in a site-specific environmental assessment for each unit.

The magnitude of wood fiber production effects is determined by the degree that treatments reduce spruce budworm populations. Both carbaryl and *B.t.* have demonstrated varied effectiveness in past projects. Contemporary projects, however, use improved formulations of insecticide, different application parameters, and revised timing of application. Operational evaluations of recent projects utilizing *B.t.* in eastern Oregon showed very acceptable results in spruce budworm population reduction.

Budworm population levels in the several years following treatment are uncertain. Sources of reinvasion may be present within, or adjacent to, any treated unit. If these sources cause populations to increase in a treated area, a second insecticide application may be needed to avert predicted timber losses. Similarly, if populations rise due to resurgence from endemic or residual populations, a second treatment would also be needed.

Cumulative effects on timber production would be a reduction in volume lost due to reduction of height growth and mortality.

Alternative A - No Action

Harvest volume impacts due to tree mortality will depend upon both the intensity and duration of the infestation. In addition, stocking levels, degree of mortality concentration, distribution of mortality among diameters, nonhost growth interactions, physiological stem damage, stand vigor, and other conditions will substantially influence resultant final harvest volumes. In some mature stands, trees defoliated by the western spruce budworm may also be attacked by other insects such as the Douglas-fir beetle or the fir engraver beetle (Fellin and Dewey, 1982). These pests prolong the occurrence of mortality beyond the period of budworm infestation. Scattered mortality may be beneficial in some instances. For example, local woodcutters gain short-term benefits if they are allowed to salvage dead trees. In some stands, mortality of budworm host trees may actually accelerate the growth of nonhost trees.

In an extreme case, tree mortality amounted to 39 percent of the total number of trees per hectare, although it was unevenly distributed among crown classes with smaller, suppressed trees sustaining higher mortality (Alfaro et al., 1982). Harvey indicated that, in Washington, 4 percent of the trees infested by budworm had died. Therefore, mortality was not considered a significant effect of budworm defoliation when looking at the infestation area as a whole.

Impact information collected in several moderately damaged stands in 1986 on the Malheur National Forest showed Douglas-fir mortality ranged from 0 to 18 percent, and grand fir mortality from 0 to 5 percent. Heavily damaged stands that were sampled had little or no grand fir, with Douglas-fir mortality ranging from 6 to 23 percent. With the additional budworm damage that has occurred in 1986, 1987, and expected to occur in 1988, the amount of mortality is expected to increase.

Under this alternative, forests would exhibit a maximum amount of mortality caused by an outbreak allowed to continue until collapse due to natural regulating factors.

Alternatives B, C, and D

With the action alternatives, there would be very little budworm-caused mortality in undamaged stands. In stands which have already experienced tree mortality, some of the additional mortality expected would be averted. The amount of mortality avoided would be dependent upon site and stand conditions.

Potential for Top-kill and Deformity

Alternative A - No Action

Top-kill, resulting from defoliation in timber stands, has three important consequences. First, height growth is reduced during the infestation. Second, when growth resumes, deformation is likely. Third, in large trees, stem decay may occur. In general, assessments of top-kill have shown its frequency to vary among and within stands. Evidence of old

top-kill was found in 11 percent of the standing Douglas-fir surveyed in British Columbia, but ranged from 0 to 70 percent within individual stands (Collis and Van Sickle, 1978; Shepherd et al., 1977). In Idaho, 20 and 70 percent of the grand fir in two stands had evidence of top-kill from previous budworm outbreaks (Ferrell and Scharpf, 1982). In eastern Oregon, Sandquist and Gregg (1985) evaluated bare top (i.e., portion of top devoid of foliage after the current year's defoliation has taken place) as a percentage of tree height on four 10-point cluster plots. Bare tops were expressed in percent of total tree height. Percent of grand fir and average percent of bare tops ranged from 7.7 percent with an average of 1.8 + 7.2 percent bare top, to 94.2 percent with an average of 13.6 percent + 6.4 percent bare top.

Impact information was collected on the Malheur National Forest in the spring of 1986, in stands showing moderate to heavy damage after 4 or 5 years of visible defoliation. In stands with moderate damage, the percentages of Douglas-fir top-killed for small (0-23 ft. tall), medium (23-46 ft.) and large trees were 67, 75, and 55 respectively. For grand fir, the percentages were 55, 85, and 76. Of the trees that had been top-killed, the average percentages of total tree height killed were 8, 7, and 4, for small, medium, and large Douglas-fir, respectively, and 4, 4, and 4 for grand fir. Heavily damaged stands sampled were composed primarily of Douglas-fir with little or no grand fir. The percentages of small, medium, and large Douglas-fir top-killed were 86, 70, and 83, respectively; the percentages exhibiting bare top were 95, 92, and 90. The percentages of total tree height top-killed were 9, 8, and 6 for small, medium, and large trees, respectively; for bare top these percentages were 32, 28, and 16. This suggests the amount of top-kill has increased since the 1986 defoliation, and will increase more if there is additional defoliation in subsequent years.

Under the No-action Alternative, the maximum amount of top-kill and deformity caused by a full-term budworm outbreak would be experienced.

Alternatives B, C, and D

Under these alternatives, top-kill and deformity due to budworm damage as described in Alternative 1, could be averted in stands which have not yet experienced top-kill. In those stands which already have budworm-caused top-kill, the amount of additional top-kill could be decreased.

Seed Production Potential

Alternative A - No Action

Western spruce budworm infestations will cause damage to Douglas-fir, grand fir, and western larch cones, but the extent of this damage is unknown. In Montana, heavy budworm infestations have resulted in total failure of Douglas-fir seed crops, resulting in a lack of natural Douglas-fir regeneration in areas that suffered budworm-caused tree mortality (Dewey 1969, 1972). Reardon et al. (1984) found budworm caused visible damage to about 98 percent of the Douglas-fir cones in an area with high budworm populations.

Under this alternative, forests will exhibit a reduction in seed production which can be attributed to a budworm outbreak which is allowed to continue until it collapses naturally. Natural regeneration of the host species would be reduced during the outbreak.

Alternatives B, C, and D

Application of *B.t.* to infested areas could avert much of the budworm-caused seed damage, and seed production would be greater than that under the No-action Alternative. The chances of establishing stands through natural regeneration would be increased.

The cumulative effects of implementation of Alternative A would be continuing and increasing loss of seed production. Alternatives B, C, and D would have no cumulative effects on seed production.

There are no conflicts expected between any of the action alternatives and other plans and policies for management of the timber resource.

Mitigating Measures

The action alternatives would mitigate additional loss of fiber and seed production due to the current western spruce budworm outbreak.

INSECT COMPLEX

Because of uncertainties about western spruce budworm behavior and population dynamics, the ability to achieve a lasting reduction in budworm populations is a concern. Gathering precise information about factors affecting populations before and during an outbreak is a slow and difficult process because the budworm has broad ecological tolerance limits. Each new outbreak provides more information about the budworm and how it interacts with its environment. Such information is vital to making decisions when selecting management alternatives during an outbreak and developing ways to prevent future outbreaks. When information is lacking, the uncertainties must be identified and evaluated in order to make the best selection from a range of alternatives. The following discussion addresses six categories of

uncertainties identified during scoping for this analysis; the outbreak cycle, reinvasion, resurgence, timing, tolerance, and efficacy:

Outbreak Cycle

Dramatic increases in an insect population can be the result of a wide range of factors. A change in weather, food quantity and quality, or biological enemies can, separately or together, cause an outbreak of a particular species. Two conditions currently believed to cause outbreaks of the western spruce budworm are an abundant food supply (extensive stands of Douglas-fir and true firs) and favorable weather (Fellin et al., 1983).

Human intervention in the ecosystem through timber harvesting practices and control of wildfires has led to large acreages of true fir and Douglas-fir (West, 1969; Hall, 1980; Schmidt, 1981). This readily available food source, combined with favorable (warm and dry) weather during May, June, and July, can lead to an outbreak (Hard et al., 1980; Ives, 1981; Twardus, 1982). Natural enemies, such as parasites and predators, both vertebrate and invertebrate, apparently exert little control over budworm populations moving into an epidemic situation (Miller and Renault, 1976; Ives, 1981; Campbell and Torgersen, 1982; Torgersen et al., 1984). Natural enemies exert their greatest pressure on budworm populations at endemic levels and during the last stages of an outbreak decline. Weather and, in some cases, starvation due to lack of host foliage appear to be the most important factors resulting in the decline of an outbreak (Fellin and Schmidt, 1973; Fellin et al., 1983).

Prolonging a budworm outbreak or increasing the frequency of outbreaks through the use of insecticides is potentially a problem but is insignificant in comparison to the proliferation of extensive areas of the preferred hosts (Blais, 1983; Fellin, 1983). The philosophy about using insecticides in western spruce budworm management has changed from ending an outbreak with one application to using a number of applications to provide trees some respite from heavy defoliation (Fellin, 1983). This strategy allows for an early treatment, theoretically resulting in greater overall benefits. A second treatment is allowed, if necessary, to assure attainment of the benefits expected. The protected food source in treated areas will remain available to support budworm populations, but with other mechanisms (such as weather) as apparent controlling factors, the outbreak should eventually decline whether or not an area is treated. Niwa et al., 1987 found that two *B.t.* formulations, Thuricide 32LV and San-415 at 20 and 30 BIU/ha did not affect the percentage of parasitism or species distribution of parasites between *B.t.*-treated plots and controls.

Reinvasion

This uncertainty concerns the ability of the western spruce budworm to move into and reinfest treated areas from adjacent untreated areas. In the West, the budworm's pattern of both short- and long-distance movements is not known. The lack of techniques and the difficulty in accurately recording moth dispersal have been barriers to the study of adult movements. When disturbed, or upon encountering competing larvae, budworm larvae drop from branches on silken threads and can be carried by the wind to other trees. Movement by this means is generally over short distances (0 to 500+ feet), depending upon the length of the thread, size of the larvae, distance above the ground, and wind speed (Batzer, 1968). Small larvae, just out of the overwintering stage, could be carried for miles with favorable wind conditions. The importance of this larval "ballooning" in reinfesting large areas is probably low due to the low chance of successful establishment of large numbers of aerial-born larvae (Batzer, 1968).

It is reasonable to assume that in the absence of substantial geographic barriers or breaks in host-type, adult moths will move freely in their search for host plants. In Oregon and Washington, past budworm control projects using DDT resulted in less than 1 percent of the areas being retreated because of "reinfestation" (Dolph, 1980). One reason for this success could have been the use of the persistent chlorinated hydrocarbon insecticide over large areas, leaving few reservoirs of budworm population. In other western regions, the number of areas needing retreatment has been higher (Fellin, 1983). The treatment of smaller units (AU's) with adjacent infested but untreated areas, as well as the need for untreated buffer strips along streams and other bodies of water when using only chemical insecticides, has led to recognition of the possibility of reinfestation and adopting a multiple-treatment scenario for the alternatives considered in this analysis. Depending upon the year of the outbreak, the economic analysis may factor two applications of insecticide into the benefit/cost analysis.

Resurgence

The third uncertainty is whether budworm populations, reduced by treatment, remain at low levels or build back up (resurge) to outbreak numbers. In the Pacific Northwest, control of the western spruce budworm has generally kept populations at acceptable levels for the remainder of the outbreak (Dolph,

1980). One reason for success in prior outbreaks could have been the use of DDT, a persistent chlorinated hydrocarbon insecticide, over large areas in the 1950's. No resurgence was noted for the projects using carbaryl in the late 1970's. With the food source remaining available and continued weather conditions conducive to population buildup, it is reasonable to assume that, given enough time, populations could build back up to an outbreak level. The time required for buildup would be directly related to the control effort's effectiveness which is dependent upon the insecticide used, its dosage and coverage, the timing of application, and the weather during and after application (Stock and Robertson, 1984). The lower the budworm population densities are suppressed and the least impact on natural enemies, the higher the probability the population will not resurge. It is expected that monitoring of control efforts taken in the current northeast Oregon outbreak beginning in 1982, will provide information about this uncertainty. In past outbreaks, treatment usually began at least 3 to 4 years into the outbreak. During the current outbreak, treatment began as early as the second year of visible defoliation. With this relatively early treatment, some population resurgence has been found, similar to the 1977 budworm control project in New Mexico (Telfer, 1983).

Smirnoff's (1983) biochemical analyses showed that *B.t.* treatments had a detrimental effect on eastern spruce budworm vigor. Carbamate and organophosphate chemical insecticides, as a result of stimulation of the budworm by sublethal dosages, encouraged the resurgence of vigorous populations. In the East, foliage protection is the objective of budworm control rather than population reduction. This strategy may result in more sublethal effects than the population reduction strategy used in the Northwest and considered in this analysis.

Timing

Throughout its range, detectable populations of budworm appear to persist indefinitely in stands that contain a substantial proportion of suitable hosts. Populations in these stands have exhibited one of three numerical patterns. The first pattern, chronically high populations, occurs in many stands. According to Johnson and Denton, (1975) 14 percent of the outbreaks persisted for at least 9 years, and 35 percent persisted for at least 4 years. In the second pattern, outbreaks may last only 1 or 2 years and result in minimal damage. This accounts for about 48 percent of budworm outbreaks. Persistence at sparce, nondamaging levels is the third numerical pattern.

When visible defoliation is first noted, there is no known way to determine which of the first two patterns the population will take. Therefore, rather than expend resources to protect the forest from an outbreak which may never become damaging, managers prefer to wait until it is likely that the outbreak will be chronically high. Treating early in an outbreak does not prevent "spread" of budworm. Experts believe some environmental factor "releases" budworm from factors normally controlling their numbers and, that over large areas, populations increase. The increase is apparent in some areas before other areas.

Tolerance to Insecticides

The development of population tolerance to insecticides generally requires heavy selection pressure from the repeated use of a particular insecticide. However, selection pressure on only one generation may lead to a greater tolerance in some cases (Robertson and Stock, 1985; McGaughey, 1985). Robertson and Stock, 1985 found a general pattern of greater population tolerance to carbaryl in areas previously treated with DDT. There were also differences in tolerance to carbaryl associated with prior treatment with carbaryl and malathion. A shift toward greater tolerance may have occurred in subpopulations of the budworm in sites on the Okanogan and Boise National Forests, where carbaryl, or both carbaryl and malathion had been applied. Where fenitrothion, malathion, and carbaryl were applied in successive years, no greater tolerance was found than in untreated areas.

It is generally considered difficult for insects to develop resistance to microbial insecticides, such as *B.t.*, because of their complex modes of action. One report, however, indicates that *Plodia interpunctella*, a lepidopteran pest of stored grain, has developed resistance to commercial formulations of *B.t.* within a few generations (McGaughey, 1985). The report indicated the stored grain environment provided an ideal situation for resistance development. To develop a similar resistance in a field crop environment would require repeated applications over a wide geographic area for several years. Such a situation has not existed in the case of western spruce budworm treatments in the Northwest.

Efficacy

Aerial application of insecticides is very complex because there are so many variables that are uncontrollable. Differences in elevation, slope,and aspect result in varying times of insect and foliage development over an area. This sometimes makes it

difficult to time the spraying of an area. The foliage must be expanded in order to present a surface for spray droplet deposition. The insect must be in a developmental stage to be freely feeding, and exposed to the spray deposit before the deposit degrades and is not useful. Weather and atmospheric conditions must be within certain limits in order to effectively atomize the insecticide formulation from the aircraft and allow its movement to the forest canopy. Careful attention to each of these variables increases the probability of budworm larvae consuming a lethal dose of insecticide.

Alternative A - No Action

Use of the No-action Alternative has no effect on achieving lasting budworm population reductions. When the No-action Alternative is selected, the outbreak would be allowed to run a natural course of rise, peak, and decline. Weather, parasites and predators, disease, and food supply would be allowed to exert their normal control over the outbreak cycle. Use of this alternative does not preclude the long-range prevention of budworm outbreaks through current and future forest management practices.

Alternative B

Applying *B.t.* is not considered likely to prolong the outbreak. Application should have no effect on natural enemies. When populations of budworm are suppressed, the natural enemies should be able to again exert their controls.

Reinvasion from untreated areas within the treatment areas is not a problem as no buffer strips are required.

Resurgence is not expected to be a problem because *B.t.* does not stimulate vigorous populations when areas receive sublethal doses.

The use of *B.t.* would not affect the timing of treatment of damaging populations.

It is unlikely that budworm populations would develop a tolerance to *B.t.* applications.

Quality *B.t.* applications are likely to suppress budworm populations below the established threshold of less than an average of 1 larva per branch tip. *B.t.*'s mode of action is that of a stomach poison. It has a useful life on foliage of at least 14 days.

Alternative C

Applying carbaryl is not considered likely to prolong the outbreak, and should have only minor effects on natural enemies. Populations are expected to recover to exert their controls in time to prevent resurgence.

Reinvasion from untreated areas within the treatment areas is a potential problem as buffer strips are required to protect the water resource from significant amounts of insecticide. Depending upon the resource to be protected, and the topography, the buffer strips could be quite wide and large reservoirs of budworm population could be left untreated.

Resurgence is a potential problem with carbaryl; it was experienced in New Mexico, and also to a minor extent in Oregon, during the current outbreak. Sublethal doses caused by poor application can stimulate vigorous populations.

The use of carbaryl would not affect the timing of treatment of damaging populations.

Studies show budworm populations can develop a tolerance to carbaryl applications.

Quality carbaryl applications are likely to suppress budworm populations below the established threshold of less than an average of 1 larva per branch tip. Carbaryl's mode of action is that of a stomach and contact poison. It has a useful life on foliage of 10 to 14 days.

Alternative D

Selection of either *B.t* or carbaryl would allow managers to use the one in a particular situation which best meets the needs of a particular situation. When there is no practical difference, or no concern about potential effects, the choice may be made on economic or other reasons.

Wildlife

Alternative A - No Action

Depending upon extent and severity, budworm-caused timber stand defoliation has the potential to adversely affect big-game habitat. Rocky Mountain elk and mule deer use timber stands as hiding and thermal cover. These stands, if substantially affected by spruce budworm defoliation, could lose many of the characteristics of cover. Thomas and Leckenby (1984) felt that tree canopy closure was not significantly affected in most areas of defoliation. Spruce budworm defoliation characteristically occurs in the uppermost parts of tree crowns, whereas the basal portion of the crown (which is damaged the least by budworm feeding) determines the percentages of crown closure in a stand and the stand's estimated value as thermal cover. Thomas and Leckenby felt that loss of thermal cover would not be substantial. They also felt that although hiding cover would be lost, the amount would not be great, and increased forage production in the affected areas could compensate for cover losses when determining overall habitat effectiveness. Thomas (1985) felt no

economic values could be assigned to these cover losses due to the offsetting factors. Economic evaluations of budworm impacts upon big game hiding cover in Montana have been included in a recent environmental assessment on the Gallatin National Forest. Review of that process indicates, because of differing stand characteristics and basic assumptions about tree mortality in the Oregon and Washington infestations, the process used in Montana is not considered applicable to this EIS.

Extensive, long-duration spruce budworm infestations provide insectivorous birds and mammals an abundant food supply. Localized areas are expected to experience population increases in some species in response to this abundant forage. It is not known whether the total predator populations respond proportionately to increased budworm numbers, or whether individuals are drawn into an area by greater foraging opportunities. Arthropod predators of spruce budworm also find abundant prey. There is no indication these predator populations respond proportionately to the increased availability of spruce budworm as prey (Torgersen, 1983).

Spruce budworm infestations, and resultant top-kill and tree mortality, provide slight benefits to cavity-nesting species and those species using spike tops as perches (Bull, 1984) because tree mortality usually occurs in trees less than 10 inches diameter at breast height (DBH). These small-diameter trees are, most often, unsuitable nesting sites for cavity nesters.

Taking no action, and allowing continued spruce budworm infestation, will result in minor reductions of hiding and thermal cover for big game. Offsetting these losses will be an increase of forage production associated with reduced tree crown cover. Both effects are expected to be of little consequence.

Beneficial effects include slight increases in nesting habitat for cavity nesters and perches for raptors as a result of tree mortality and top-kill. Abundant insect populations are also beneficial to insectivorous wildlife species. Benefits of abundant forage are transitory, lasting only as long as the current infestation.

Overall, it appears general wildlife populations benefit slightly from the current spruce budworm infestation. Benefits are transitory and are not expected to last much longer than the infestation.

Alternative B

Impacts upon wildlife result primarily from increased human activity associated with treatment projects. Coverage of large areas by personnel and equipment increases the disturbance factor. Species sensitive to this type of disturbance, such as bald eagles, golden eagles, ospreys, and spotted owls, nest in some affected areas. Nest abandonment because of disturbance by low-flying aircraft or activities of ground personnel could occur. Concerns about disturbance effects on deer, elk, and bighorn sheep have been raised; for instance, lactating mothers may abandon their young.

Thomas and Leckenby (1983) felt the potential for such an effect exists, but due to the limited duration of disturbance in each spray block, significant impacts were unlikely.

Field tests have not revealed any deleterious effects of *B.t.* on populations of birds and mammals. Studies in Algonquin Park and Spruce Woods in Canada, found no significant difference between populations of birds and mammals on sprayed plots versus populations on untreated plots (Buckner et al., 1974). In a second test, aerial application of *B.t.* (Dipel WP) applied at a rate of 0.5 lb./acre to a Scotch pine plantation containing a large population of nesting mourning doves, apparently did not affect or disturb the birds (Kearby et al., 1975). Twenty-four hours after spraying, nestlings were observed still in their nests and adults were flying about the plantation. After 28 days, adults were still numerous and nestlings had fledged. A study to determine secondary effects of *B.t.* spray on chickadees was done during the 1986 Gypsy Moth Project in western Oregon (Gaddis and Corkran, 1986). Spray areas were treated three to four times with 16 to 20 BIU's per acre. Results indicated there was a significant difference in the number of lepidoteran caterpillars available for food between treated and untreated areas; however, this did not affect success of the chickadee reproductive process or fledgling development; chickadees simply found other food. There was no significant difference in time spent foraging for food between treated and check areas. In another study conducted by the Oregon State Fish and Wildlife Department, clutches of pheasant eggs received simulated applications of *B.t.* spray. There was a significant decrease in egg hatch between treated and nontreated eggs. *B.t.* applications with and without the enzyme, chitinase, had no detectable impact on small mammal abundance (Buckner et al., 1974). Field mice (*Napaeozapus insignis* Miller and *Peromyscus maniculatus* Wagner), shrews (*Blarina brevicaudia* and *Sorex cinereus* Kerr), voles, and chipmunks (*Tamias striatus* L.) were examined. Eighty percent of a small sample of adult females had placental scars, indicating that reproduction was unaffected.

Extensive laboratory testing has been done on the effects of *B.t.* upon wildlife and domestic species. The results of these tests have been published in the following documents:

"Environmental Assessment Western Spruce Budworm Management in Northeastern Oregon", Appendix F, USDA Forest Service, Pacific Northwest Region, 1984;

"The Toxicology Profile", Abbott Laboratories, 1982;

"Gypsy Moth Suppression and Eradication Projects Final EIS", USDA Forest Service and Animal Plant Health Inspection Service, March 16, 1984.

"A Comprehensive Review of *Bacillus thuringiensis* var. *kurstaki*" by J.F. Sassaman, 1987.

Except for lepidopterans, no toxicity to zooplankton, arthropods, fish, birds, mammals, and other wildlife or domestic species, has been demonstrated at levels recommended for field application. In fact, only extremely high concentrations (such as might occur with a spill) have demonstrated any effect.

Livestock operators have expressed concern regarding the use of bacteria in areas where livestock graze. *B.t.* has been identified only once as a pathogen in mammals (causal agent in a case of bovine mastitis). Whether other factors were involved in this case is not known (USDA Forest Service/Animal and Plant Health Inspection Service, 1984).

Evidence from laboratory testing on effects to domestic species found B.t. produced no adverse effects, and even if ingested in large quantities, will not survive in the animal's digestive system. Regulatory agencies have placed no restrictions on the use of *B.t.* near livestock or food crops. *B.t.* has been widely used to control insect pests other than western spruce budworms. *B.t.* is a lepidoptera-specific insecticide; therefore, only phytophagous insects in the Order Lepidoptera (butterflies and moths) are affected. In field tests in Nova Scotia, where *B.t.* was the only insecticide applied to an apple orchard over a 4-year period, population levels of lepidopterous insects were reduced, but there was no observed effect on predaceous insects (Jaques, 1965).

Spruce-fir stands in Algonquin Park, Ontario, Canada, and mixed forest containing mature spruce stands, poplar bluffs, and areas of dense brush and open fields in Spruce Woods, Manitoba, were sprayed with formulations of Thuricide 16B or Dipel WP (trade names of *B.t.* formulations). Although some declines in populations of nontarget insects were observed, comparison with the controls indicated the declines could not be attributed to the spraying (Buckner et al., 1974). These studies also reported no significant increase in mortality among foraging bees as a result of *B.t.* treatment. Other studies of the effects of *B.t.* on honey bees (Krieg, 1962; Krieg, 1963; Burges and Bailey, 1971; Franz et al., 1967; Cantwell et al., 1966; Wilson, 1962) found no evidence these insects would be harmed by *B.t.* at the levels commonly used in spray operations. *B.t.* has been shown to be nontoxic to bees at levels as high as 726,000 spores per bee (Atkins et al., 1975).

One study has shown *B.t.* to be fatal to earthworms at concentrations 104 to 105 times higher than that which would occur in the soil after normal application in the field (Smirnoff and Hempel, 1961). However, these studies were carried out using *B. thuringiensis* var. *thuringienesis*, a producer of beta-exotoxin which could have influenced the results. Experiments using Dipel (16,000 International units/mg) at dose rates of 60, 600, and 6,000 mg/square meter on forest plots, and Bactospeine (1,000 IU) at a dose rate of 30 g/cubic meter, show worm density after spraying was not significantly different from worm density prior to spraying (Bentz and Altwegg, 1975). The formulations considered for use against spruce budworm contain a variety of the *B.t.* bacterium that does not produce beta-exotoxin.

Other concerns associated with a *B.t.* spray project center around the impacts upon nontarget lepidopterans, and the impact a reduction of lepidopteran populations will have upon species that prey upon these insects. Many butterflies and moths will have pupated or completed metamorphosis prior to the proposed early summer budworm treatment period. Only those phytophagous larvae that feed on external plant parts will be susceptible to *B.t.* Those insects that feed inside plants, such as borers, needle miners, and gall moths, will not be affected. Additionally, under the most favorable conditions for control, a percentage of insects, even target species, survive control efforts. In a study done during the 1986 Gypsy Moth Project in western Oregon, it was found the population of lepidopteran larvae was reduced significantly within 48 days following the last treatment. However, there was no significant difference between populations in the control and treated areas 68 days following the last treatment (Miller, 1986). Considering these combined factors, it is highly unlikely that significant long-term impacts upon nontarget lepidopteran populations will occur.

Since *B.t.* is not a broad-spectrum insecticide and affects only lepidopterans (moths and butterflies), expected impacts upon terrestrial organisms are slight. Most beneficial insects would not be affected. Some nontarget moth and butterfly species, which are in the larval stage at the time of treatment, may be at risk of experiencing population reductions for a year or two. Insect populations representing food supplies for birds would not be appreciably affected, so the risk of nest abandonment would be slight.

Implementation of Alternative B would result in minimal disturbance of wildlife populations, and would have little adverse impact to survival and abandonment of young. Mitigation measures controlling the timing of treatment and no-treatment buffer zones around critical areas such as bald eagle nests or bighorn lambing areas, will minimize disturbance.

A number of vertebrate wildlife species will be exposed to some level of *B.t.* under this alternative. Species, including those of special interest that are known or suspected to occur in at least one analysis unit, are listed in Table IV-XV and Table IV-XVI. None of these species will experience serious adverse effects as a result of exposure to *B.t.*

Alternative C

The risk to wildlife species from spruce budworm suppression with carbaryl is a function of the inherent toxicity (hazard) of the insecticide to different organisms, and the amount of chemical (exposure) those organisms may take in as a result of a spraying operation. The wildlife species risk analysis compares estimated acute exposures of representative species with acute toxicity levels found in laboratory studies.

For wildlife risks, the criteria used by the Environmental Protection Agency (EPA, 1986) in ecological risk assessments were used to judge absolute risks to the different representative species. The EPA criteria compared an estimated environmental concentration (EEC) with a laboratory-determined LD_{50} or LC50 for the most closely related laboratory test species. (See Glossary for a definition of LD50 and LC50.)

Where the EEC exceeds 1/5 LD_{50} or LC50, EPA deems it a significant risk that may be mitigated by restricting use of the pesticide. EPA judges EEC's that exceed LD50 of LC50 as unacceptable risk levels. Doses below the 1/5 LD50 level are assumed to present a low risk. In this risk assessment, an organism's total estimated dose (rather than an EEC) is compared with the laboratory toxicity level because the dose comes from all exposure routes, not just feeding.

Analysis of insecticide risk to wildlife compared estimated acute doses for the representative wildlife species with available hazard information on the most closely related species. Because carbaryl showed no tendency to bioaccumulate, long-term persistence in food chains and subsequent toxic effects, such as those resulting from use of persistent organochlorides, are not considered a problem and are not examined in the risk analysis. No analysis of chronic wildlife dosing was done because the insecticide degrades relatively rapidly and sites are normally treated only once a year.

Wildlife Toxicity Surrogates

The toxicity of insecticides to wildlife varies among individuals of the same species (intraspecific), between different species (interspecific), and, often most markedly, between different classes of animals. Thus, an insecticide may be more toxic to birds than to mammals, or more toxic to fish than to birds. However, toxicity testing has been conducted on relatively few wildlife species, with testing confined to a few avian and mammalian wildlife species. Laboratory animal studies have been done on inbred strains of test animals, particularly rats and mice, to estimate human toxicity.

Toxicity data on the most closely related avian or mammalian species are used for the wildlife risk comparisons. Where no data on a mammalian wildlife species (for example, mule deer) are available, data on laboratory rats, mice, dogs, rabbits, or guinea pigs are used for comparison with representative species doses.

The U.S. Fish and Wildlife Service in its testing of nearly 200 chemicals on terrestrial vertebrate wildlife species (Hudson et al., 1984), tested 19 pesticides, principally organophosphate and carbamate insecticides, on the adult stage of the bullfrog. No tests were done on reptiles. There was a good correlation (r = 0.67) between the LD_{50}'s for the bullfrog and the LD_{50}'s for the mallard, when 17 of the 19 chemicals were used in a prediction equation. The bullfrog LD_{50}'s for 14 of the 19 chemicals were used in a prediction equation, and were higher than those of the mallard.

In its studies of aquatic species (Mayer and Ellerseick, 1986), the U.S. Fish and Wildlife Service tested 20 and 13 pesticides, respectively, on the immature stage (tadpole) of two amphibian species--Fowler's toad and the western chorus frog. Most of the tests were on organochloride and organophosphate insecticides. There was a poor correlation (less than 0.10) between tadpole and mallard or rat LD_{50}'s for the same pesticides. The U.S. Fish and Wildlife Service also reviewed the available data on the toxicity of environmental contaminants to reptiles (Hall, 1980). Most of the data consisted of residue levels of organochlorides in reptiles collected after field applications. There were no data of the type reported in the above amphibian studies relating dose levels to lethality. The author noted, however, that bird data could serve as a guide for reptile toxicity since birds were closely related to reptiles, although, in general, reptiles appeared to be more susceptible to pesticides than birds or mammals.

Thus, for carbaryl and additives in this risk assessment, suitable data are lacking for terrestrial stages of amphibians and for reptiles. Because there is a reasonable correlation between avian and amphibian toxicity (as indicated in the mallard versus bullfrog LD_{50} analysis), and reason to suspect the same of avian and reptilian toxicity as noted by Hall (1980), available avian toxicity data were used as surrogates for both amphibians and reptiles.

Wildlife toxicity reference levels used to assess the risks of the insecticides are given in Appendix F.

Wildlife Exposure Analysis

Appendix F discusses total realistic and extreme dose estimates for 14 representative wildlife species for carbaryl.

The wildlife risk assessment tends to overstate risks and many assumptions are quite conservative. For example, no degradation is assumed to occur, and all pesticide sprayed is assumed to be biologically available. In extreme exposures, the entire diet of an animal is assumed to consist of contaminated items, while realistically, a significant percentage of the diet is assumed to be contaminated. Dermal exposures are assumed to come directly from pesticide spray, and indirectly, from brushing up against treated vegetation. Birds and mammals receive dermal doses through their skin and from grooming. This accumulation undoubtedly overestimates doses, even in realistic cases. Nevertheless, when dose estimates exceed the EPA risk criterion, and more so, when they exceed the LD_{50} for the most closely related laboratory species, there is a clear risk of adverse effects on individual animals.

Wildlife Risk Overview

In general, based on available toxicity data and proposed application rates, risks to wildlife are low to negligible in the spruce budworm suppression program. Except for small mammals and smaller birds, realistic doses seldom exceed 10 mg/kg. The realistic dose estimates are well below the EPA risk criterion of 1/5 LD_{50}, and are far below the laboratory species LD50 for the majority of species.

Local populations of small mammals, small birds, amphibians, and reptiles may be adversely affected when large areas are treated. The reproductive capacity of these species is generally high enough to replace those lost within the next breeding cycle. Populations of larger mammals and birds, and any domestic animals present, are not likely to be affected at all.

There are very few studies on which to base conclusions regarding toxicity levels. However, the conservatism used in estimating wildlife doses should compensate for much of the uncertainty in the toxicity data base.

Risks to wildlife from individual chemicals used in spruce budworm suppression are shown in Tables IV-XIII and IV-XIV. Literature references for toxicity levels in laboratory species are given in the wildlife hazard analysis.

Carbaryl

No realistic or extreme doses of carbaryl exceed the EPA risk criterion of 1/5 LD_{50}. Alternative C would not present a risk to wildlife.

Diesel Oil and Kerosene

Wildlife exposures are far below the EPA risk levels for these two chemicals and, under this program, there would be no risk to wildlife from their use.

Risk to Bird Eggs and Nestlings

Bird eggs or nestlings exposed to insecticides or diesel oil and kerosene, would result in some risk of death or injury. Nestlings would get a dermal dose depending upon how well the nest was protected, and an oral dose depending upon the amount of residue deposited on their food items. Bird eggs are far less likely to be affected by insecticides because they are not likely to be left uncovered during a spray operation. The parents' body would protect eggs from direct deposition, although a minor amount of insecticide might reach the egg via the feathers of either parent during incubation. Diesel oil and kerosene present some risk to bird eggs by penetrating the shell more easily than water-based insecticides, and are both relatively toxic to developing embryos. The eggs are not likely to receive an appreciable amount of these chemicals since they are normally protected by an incubating adult.

Invertebrates

Some aquatic insects in the orders Plecoptera (stoneflies) and Ephemeroptera (mayflies) are highly sensitive to low levels of carbaryl. Trichoptera (caddisflies) and Diptera (true flies) are also sensitive to carbaryl. There may be a 50- to 100-percent reduction in aquatic insect populations in treated streams and ponds (Burdick et al., 1960). Mount and Oehme (1981) found that applications of 1.25 lbs. of carbaryl per acre were not directly toxic to fish, but food items were reduced by 97.2 percent. LOTEL (1975) reported that in a stream treated with 1 lb carbaryl/acre, each sampling station recorded a residue of at least 40 parts per billion (ppb) and a peak residue of 80 ppb. The biological impact was indicated by increased drift of dead and dying stoneflies, mayflies, caddisflies, and true flies.

The effects of 2 consecutive years of spraying on other aquatic organisms appear similar to those observed in areas treated just once (Trial, 1978, 1979; Courtemanch and Gibbs, 1978). These effects include loss of stonefly species from individual streams and altered generic assemblages for an indefinite period (Trial, 1978, 1979). During the 1979 Maine spruce budworm spray project, a study of buffered streams by McCullough and Stanely (1980) indicated that benthic invertebrate fauna were not adversely affected. Also, the numbers of drifting invertebrates were substantially lower than in previous years. Long-term impacts appear to be species susceptiblity and recolonization ability. Two consecutive years of spraying with carbaryl reduced populations of stonefly and susceptible mayfly genera to near zero.

Carbaryl (Sevin 4-Oil) was applied to woodland ponds in Maine at a rate of approximately 1.85 lb. a.i./acre (.84 kg a.i./acre). Caddisfly populations were temporarily reduced. Most severely affected were the amphipods (*Hyallela azteca*), which were reduced to nearly zero. This group failed to recolonize in some ponds for up to 30 months after spraying (Gibbs et al., 1984).

Carbaryl

Mammalian Toxicity

Carbaryl is considered moderately toxic to mammals and slightly toxic to birds. The acute oral LD_{50} of carbaryl ranges from 150 mg/kg to 710 mg/kg for mammalian species (Ghassemi et al., 1981; Hudson et al., 1984; NLM, 1986b). Carbaryl is used on poultry, cattle, and pets to control insect pests. Acute oral LD50's for mammals and birds are shown in tables located in Appendix F.

Several studies have examined the effects of carbaryl on wild populations of small mammals with varying results, depending upon application rates. The proposed rate for this program is 0.5 lb a.i./acre (8 oz a.i./acre) of carbaryl, lower than any of the reported studies. In Canada, no changes were observed in small mammal populations 2 months after spraying forested areas with carbaryl for spruce budworm control (Buckner et al., 1973). A study of an area in New York treated with 1.25 lb a.i./acre of carbaryl reported no adverse effects on small mammals or deer (Connor, 1960).

Denisova (1973) reported a decrease in mole and rodent populations in forests treated at a high rate (4.46 lb per acre) with carbaryl. No recovery of populations was reported within 2 years. Tissue residues of carbaryl in males were 5 mg/kg in reproductive organs, 3 mg/kg in liver, and 1.5 mg/kg in muscle.

Barrett (1968) reported a decline in cotton rat populations, an increase in house mouse populations, and no change in old field mouse populations following treatment of a millet field at 2 lb a.i./acre of carbaryl. Carbaryl residues in millet were 35 ppm. There was a 4-week delay in the reproductive cycle of the cotton rat. Laboratory studies by Barret supported these findings. Dose of 1.1 mg/adult/day (similar to those in the field study) resulted in a greater than 50-percent decline in the number of female cotton rats giving birth, and in the total number of litters. At the same dose, reproduction in the house mouse was not affected.

Avian Toxicity

The acute, or LD_{50}, ranges from 780 mg/kg to more than 2,500 mg/kg for avian species (Ghassemi et al., 1981; Hudson et al., 1984; NLM, 1986b). The LD_{50} is greater than 2,564 mg/kg for mallards. Toxic symptoms observed in birds at lethal or near-lethal doses include inactivity, ataxia, regurgitation, weakness, fluffed feathers, salivation, slowness, lethargy, tachypnea, tremors, ataraxia, tetany, paralysis, coma, and convulsions (Hudson et al., 1984).

Results of carbaryl studies on birds vary. A number of studies have reported no effect on bird populations in areas treated with carbaryl. Several studies have reported decreased levels of brain cholinesterase (ChE) activity. One study reported significant declines in bird populations, possibly resulting from reduced food supplies.

Studies have shown no adverse effects at application rates at least two times that of the rate proposed for the Forest Service spruce budworm control program (0.5 lb a.i./acre). In New York, an area was treated with carbaryl at a rate of 1.25 lb a.i./acre. No effects were observed on behavior, reproduction, or rearing of young, in 49 species of birds (Connor, 1960). Following carbaryl spraying, no significant effects were observed on nesting success, total number of breeding birds, mortality rates, or brain ChE levels (Zinkl et al., 1977). Richmond et al. (1979) reported a similar lack of adverse effects to birds in Oregon after applications of 2.0 lb a.i./acre of carbaryl. No adverse effects were reported in bird populations in Colorado after carbaryl was applied at a rate of 1.0 lb a.i./acre (McEwen et al., 1962). Bart (1979) reported no changes in bird populations or song frequency in forest plots treated at 1 lb and 5 lb carbaryl per acre. No changes in songbird populations occurred up to 3 weeks after spraying Canadian spruce forests at 1 lb carbaryl per acre (Buckner et al., 1973).

A decrease of brain cholinesterase was measured in forest birds in Montana

after applications of carbaryl at 1.0 lb a.i./acre (Zinkl et al., 1977). The authors suggested that observed depressed ChE levels may reduce a bird's ability to avoid predators and to obtain food. Another study reported no decrease in ChE levels in birds in Maine forests treated at 0.31 lb and 0.69 lb per acre (Gramlich, 1979). Knowledge is lacking regarding the minimum application rate of carbaryl that causes ChE depression. Further research is needed in this area to more accurately assess impacts on wildlife.

Forested areas in New Jersey treated in the month of June for gypsy moth control with carbaryl at 1 lb/acre, resulted in a 55-percent decrease in bird populations within 2 weeks after spraying, and showed no recovery during 6 more weeks of monitoring, or in the following year during June and July (Moulding, 1972). The unsprayed plot showed no significant changes. It was noted that canopy species were more affected than ground feeders. The author suggested the following possible explanations for the overall decline of birds: opportunistic feeding outside the sprayed area, possible reduced reproductive success, or a shift in nest-site loyalty, all of which may be a result of reduced insect populations and food supply. Doane and Schaefer (1971) have suggested the removal of gypsy moth larvae, which is an important food source for birds, could cause migration of birds out of treated areas.

Effects on Avian Reproduction

Studies indicate the possibility that extensive use of carbaryl may cause a significant reduction in reproductive success of avian species, especially quail and pheasant. DeRosa et al. (1976) found residues of carbaryl in yolks of Coturnix quail eggs produced 8.5 hours after treatment levels similar to those encountered in the field. Fecal analysis indicated carbaryl residues were no longer present at 52 hours. Exposure to a second treatment caused significant reduction in egg production in direct proportion to treatment levels. Egg viability was not affected; however, agonistic behavior was decreased in males but increased in females following pesticide ingestion. DeRosa et al., suggested these behavioral modifications may disrupt pair formation in the field, thereby jeopardizing the bird's reproductive success.

DeWitt and Menzie (1961) reported a reduction in chick production of quail when fed diets containing a total of 12,000 mg/kg or more of carbaryl during growth, winter, and production periods. Pheasants fed diets with 500 or more ppm carbaryl during the breeding season had a 50-percent reduction in chick survival. Depressed body weights were observed in quailfed diets containing 250 ppm or more carbaryl, and in pheasants fed diets containing 1,000 ppm carbaryl. The percentage of growth depression in pheasants was roughly proportional to the daily intake of carbaryl.

Japanese quail fed 50,150, 300, 600, 900, and 1,200 mg carbaryl per kg of feed (ppm) from the day of hatching to 14 weeks of age showed growth depression and increases in relative brain, liver, and kidney weights (Bursian and Edens, 1977). A slight decrease in egg production and viability was observed at the 600, 900, and 1,200 ppm levels.

Zinkl et al. (1977) also suggested brain cholinesterase inhibition, caused by treatment with 1 lb a.i./acre carbaryl, may result in reduced reproductive success through inability of birds to gather food or escape predation.

In a study involving exposure of eggs to pesticides, 40 percent of eggs injected with 5 mg of carbaryl hatched (Ghassemi et al., 1981). No eggs hatched that were injected with 2.5 mg each of malathion and carbaryl. These dosages are considered to be well above the expected and environmental exposure. In another study, hen eggs injected with 100 and 200 ppm carbaryl in acetone killed 61 and 100 percent of embryos, respectively (Dunachie and Fletcher, 1969). Teratogenic effects were caused at 50 ppm and above.

Toxicity to Honey Bees

Carbaryl is very toxic to honey bees (Union Carbide, 1980). In honey bees, the 48-hour LD_{50} for direct exposure is 1.34 ug/bee for carbaryl dust, and 1.02 ug/bee for Sevin 4-Oil dust (Atkins et al., 1973). Similar results were reported by Stevenson (1970). The LD50 for an adult bee by direct contact was approximately 1 ug or 10 to 15 mg/kg.

Carbaryl is more toxic to honey bees when ingested than from direct contact. The results of laboratory experiments indicate the LD_{50} is 0.18 ug per bee when administered by the oral route (Alvarez et al., 1970). Bees collecting pollen from treated areas may be killed in great numbers when walking over treated surfaces (Mayland and Burkhardt, 1970).

Older bees (normally the worker bees) are less susceptible to carbaryl

(Mayland and Burkhardt, 1970), and may carry contaminated pollen to the hive before they sicken and die. The young and reproductive members of the hive may also die from eating pollen (Johansen and Brown, 1972; Mayland and Burkhardt, 1970; Strang et al., 1968). Once inside the hive, the contaminated pollen may remain toxic for months (Johansen and Brown, 1972; Moffett et al., 1970).

If bees are removed beyond flight range from an area to be sprayed and not returned for 7 days after

spraying, mortality is not significant (Atkins et al., 1975, 1977; Strang et al., 1968; Union Carbide, 1981). Another method to reduce the effects of spraying carbaryl near bees is the deliberate feeding of corn pollen to the bees, which seems promising on an experimental basis (Moeller, 1972). Most recommendations include either moving the colony for a brief period, or confining the bees to their hive prior to and shortly after spraying (Agriculture Research Service, 1967, 1977).

Toxicity to Other Beneficial Insects

Because carbaryl acts as a broad-spectrum pesticide (EPA, 1980), a certain amount of toxicity to a wide variety of insects and other arthropods may be expected. Many insects in the order Hymenoptera (this order includes the honey bee) seem to be especially susceptible to carbaryl (Abu and Ellis, 1977; Adams and Cross, 1967; Plapp and Vinson, 1977; Stern, 1963).

Ladybird beetles (coccinellid) have also been found to be very sensitive to carbaryl (Afify et al., 1970; Bartlett, 1963, 1966; Colburn and Asquith, 1971; Satpathy et al., 1968; Stern et al., 1959). In general, both groups of insects are regarded as beneficial insects because they act as predators and parasites of various insect pests in crops. Comparatively less carbaryl is required to kill these beneficial insects than is needed to kill pest insects. Even parasites developing inside a treated host insect may be killed (Abu and Ellis, 1977), as will ladybird beetles feeding on poisoned aphids (Satpathy et al., 1968). A loss of these predators may occur in carbaryl-treated areas, but no permanent loss has been found in monitored spray programs (Root and Skelsey, 1969; Shepard and Sterling, 1972; Union Carbide, 1980). A fairly rapid reestablishment of these beneficial insects by immigration from areas surrounding the treated area can be expected since little residual effect of carbaryl exists several days after spraying.

Carbaryl is not toxic to all members of the order Hymenoptera and at least one important pollinator of alfalfa, the alfalfa leafcutting bee, is only moderately susceptible to carbaryl (Johansen et al., 1963; Waller, 1969). Other beneficial insects, such as the predaceous big-eyed bugs (Walker et al., 1974) and green lacewings (Plapp and Bull, 1978) are not severely affected by carbaryl (Union Carbide, 1980).

Effects on Spiders and Mites

Spiders are not severely affected in carbaryl-treated fields (Shipard and Sterling, 1972), although they have been shown to be more sensitive to carbaryl when they ingest treated prey than when they walk over treated surfaces (Hagstrum, 1970). As shown in another study, spiders quickly return to treated areas within 3 weeks after spraying (Barrett, 1968).

Carbaryl is highly toxic to predatory mites, but not as toxic to phytophagous (plant-feeding) mites (Bartlett, 1968; Dabrowski, 1969, 1970; Dabrowski et al., 1973). One investigation (Croft and Jeppson, 1970) showed that carbaryl was less toxic to predaceous mites than was previously reported in the literature. Mite predators, such as the predaceous thrips, are also susceptible to carbaryl (Holdsworth, 1968; MacPhee and Sanford, 1961). This difference in toxicity to mite predators may cause detrimental outbreaks of phytophagous mites, which are common in cotton.

Aquatic Toxicity

Concentrations of approximately 10 ppm carbaryl were lethal to three of five species of marine algae. Reproduction was not affected at 1.0 ppm. In one of the five species, growth was inhibited at 0.01 ppm (Ukeles, 1962).

Toxicity of 1-Naphthol

The major microbial degradation product of carbaryl is 1-naphthol. In a laboratory study (Stewart et al., 1967), carbaryl was shown to be 30 to 300 times more toxic than 1-naphthol to crustaceans (shrimp and crabs). In the same study, 1-naphthol was twice as toxic as carbaryl to fish and mollusks (mussels, clams, and oysters) (Butler et al., 1968; Stewart el al., 1967).

Diesel Oil

Mammalian Toxicity

Refer to the discussion in the human health hazard section of this section for details on the chronic toxicity, oncogenicity, teratogenicity, and mutagenicity of carbaryl. According to the American Petroleum Institute (1983), the major hazards to mammals from diesel oil in the environment include the adherence of oil to the fur of animals, possibly resulting in hypothermia, and sublethal effects in small mammals from contaminated forage.

Toxicity to Beneficial Insects

Based on available studies, diesel oil appears to be highly toxic to honey bees, suggesting the potential for a high degree of toxicity to other invertebrates. Diesel oil caused high mortality to honey bees during the first 24 hours after spray treatment (Moffett et al., 1972). The authors also reported toxicities of combinations of diesel oil and water, or diesel oil, water, and dimethylsulfoxide (DMSO) are less than diesel alone.

The use of adjuvants, such as spray oil, diesel oil, and surfactants, with insecticides caused slightly increased mortality of honey bees (Lagier et al., 1974).

Avian Toxicity

Diesel oil is slightly toxic to orally exposed birds. The acute oral LD_{50} of diesel oil for mallard ducks older than 1 year is greater than 16,400 mg/kg (20 ml/kg) (Hudson et al., 1984). However, traces of oil in a mallard's diet sharply reduce egg production (Biderman and Drury, 1980). Furthermore, application of 5 ul of No. 2 fuel oil on mallard eggs significantly reduced hatching success to 18 percent (control group's hatching success was 88 percent) (Szaro et al., 1978). Survival and hatchability were significantly reduced even after application of only 1 ul of oil (Szaro et al., 1978). The authors reported that application of 20 ul of No. 2 fuel oil, which covered 20 percent of the egg surface, killed all embryos. Death occurred rapidly, and appeared to be related to the aromatic portion of the oil rather than the aliphatic portion. Szaro et al. (1978) reported surviving ducklings showed no gross external or behavioral abnormalities, and no significant differences in weights in comparison with controls at hatching. Similar toxicity of diesel oil was noted in pheasant eggs which failed to hatch when sprayed with diesel oil to the point of runoff (Kopischke, 1972). Death occurred 1 to 2 days after oil was applied.

Alternative D

It is assumed *B.t.* will be applied on sensitive areas, e.g., riparian/watershed, and carbaryl will be used on all other areas. The most substantial difference between this alternative and the carbaryl-only alternative is the reduced impact on the aquatic ecosystem.

Cumulative Effects (Wildlife)

Alternative A - No Action

There is potential for substantial local impact on deer/elk cover directly related to spruce budworm.

The substantial impact on cover would result from long-term spruce budworm infestation, combined with increased tree mortality due to complicating factors such as drought and Douglas-fir beetle (Thomas 1988).

Alternative B

No substantial adverse cumulative effects are expected.

Alternative C

The extent of the adverse effect is not known at this time. The impact would be indirect because carbaryl is not persistent and does not accumulate. The cumulative effect, primarily on invertebrates, would be greater than the effects of Alternatives A or B. However, the effects are probably not substantial.

Alternative D

The cumulative effects are the same as for Alternative C.

Range

Alternative A - No Action

No detrimental effect on range is expected from the current spruce budworm outbreak.

Alternative B

A locally substantial impact on range resources could result from implementation of this alternative (the use of *B.t.*). The impact would be on noxious weed control. Biological control agents are major factors for control of noxious weeds in parts of Oregon. For example, the cinnibar moth (*Tyria jacobaeae*), a lepidopteran, is used as one agent for controlling Tansy ragwort (*Senecia jacobaea*). *B.t.* is relatively specific in its impact on lepidopterans. Close coordination with County weed control agencies and the Oregon State Department of Agriculture would be needed to mitigate any potential local impact. It is possible that spruce budworm and cinnibar moth populations may not be susceptible to *B.t.* effects at the same time.

Alternative C

This alternative, using only carbaryl to treat spruce budworm areas, has the greatest potential of all alternatives considered to have significant local impacts on range resources. The impact would be directly on noxious weed control biological control agents. Carbaryl would be detrimental to most (all) insects used in biological control of noxious weeds. The impact would be substantial in Oregon where the State Department of Agriculture, in cooperation with County weed control boards, Forest Service, BLM, BIA, etc., operates an aggressive noxious weed control program.

Alternative D

The impact of this alternative could be locally significant on range resources. The major effect is

potential loss of nontarget insects, specifically species used as biological control agents on noxious weeds.

Mitigating Measures

Close coordination with County weed control agencies and the Oregon State Department of Agriculture would be needed to mitigate any potential local impact to local cinnabar moth populations.

Threatened, Endangered, And Candidate Species

Alternative A - No Action

Under this alternative, there would be no change from the effects expected due to ongoing forest management operations.

Alternative B

Bald eagle nesting territories occur within several areas considered for treatment. A one-half-mile-radius buffer will be maintained around the nest sites. In addition, a set of mitigating measures, developed with concurrence from the U.S. Fish and Wildlife Service that will result in no effect to nesting eagles, will be incorporated in project operations plans and implemented during treatment.

A list of candidate species, which may occur in some areas, was also provided by the U.S. Fish and Wildlife Service. No effect from treatment is anticipated for these species.

The historic locations of known populations of threatened, endangered, and candidate plants on National Forest lands are kept on file. Access to this information is limited to prevent misuse.

These plants, which are located in applicable analysis units, may be affected to some degree by the application of some of the *B.t.* formulations considered in this analysis

Macfarlane's four o'clock, a federally listed endangered species, may occur within some potential analysis units. Treatment is expected to have no effect.

During *B.t.* spray projects in the Seattle, Washington, area in 1983 and 1984, using Dipel 4L and Dipel 8L respectively, some burning of new foliage on tender-leaved ornamentals and hardwoods, such as linden and vine maple, was noted. Effects were limited to the leaf area where a spray droplet actually landed, and seemed to be mechanical damage rather than chemical toxicity. The spraying occurred on sunny days, and on-the-ground personnel suspect the mineral oil carrier tended to focus light at that point and burn the foliage beneath the droplet (LaGasa, 1985).

In areas planned for treatment, the project leader will coordinate with the Forest Threatened, Endangered, and Sensitive Species Coordinator, and take appropriate action to assure that threatened, endangered, or sensitive plants are protected.

Annual plant species dependent upon insects for pollination would be adversely affected if pollinating insect populations were eliminated. However, no reductions in these populations are expected with *B.t.* treatments.

Alternative D

The effect on threatened, endangered, and sensitive species is expected to be similar to the effect of the use of *B.t.* only. The major impact would result from the activity associated with the application of any insecticide.

Mitigating Measures

Any spraying operation will be coordinated with local State and Federal land managers to ensure that appropriate protection measures are implemented to mitigate possible adverse effects to the nesting habitat of eagles and other raptors. Mitigating measures for threatened or endangered species, developed with the concurrence of the U.S. Fish and Wildlife Service, will be incorporated into the project operations plan to ensure that treatment and related activities will have no effect.

In areas planned for treatment, coordination will be done with the Forest Service Area Ecologist, or other agency counterpart, to determine what action is appropriate to assure that threatened or endangered species will be avoided if necessary.

Fisheries/Aquatic Ecosystem

Alternative A - No Action

Most data indicate that even with heavy infestations of spruce budworm, most tree defoliation would be less than 100 percent, while stem mortality over the outbreak area would be less than 3 percent. Given these values, it is unlikely that water temperatures of streams in affected areas will be significantly altered. Therefore, no effects on fisheries resulting from water temperature increases are expected. Low levels of tree mortality in riparian areas have the potential to add organic debris to streams and, thereby, enhance fisheries habitat. Sedell and Luchessa (1981) pointed

out the importance of organic debris in streams in relation to fisheries habitat.

Budworm larvae falling into streams or wetlands in areas of heavy infestation could enhance food supplies and beneficially affect fish growth rates.

The No-action Alternative, having minimal adverse impacts on water quality, would have similar minimal effects on fisheries. Minor amounts of streamside shade could be lost. Tree mortality occurring on stream sides would add woody debris to fish habitat, providing cover and pools. Fish populations would benefit from such habitat improvement. Aquatic invertebrates would not be affected by the No-action Alternative. This alternative would have the least impact or risk of impact upon aquatic invertebrates and fish.

Alternative B

Few toxic effects have been reported in studies of aquatic species exposed to *B.t.* While monitoring aquatic species on Moresby Island, British Columbia, in 1960, Todd and Jackson (1961) found no adverse effects on coho salmon fry, or on aquatic insects in streams within an experimental area treated with *B.t.* In studies in Algonquin Park, Ontario, Canada, fish and bottom fauna suffered no adverse effects up to 4 weeks after spraying (Buckner et al., 1974). Ignoffo (1973) found *B.t.* to be toxic to coho salmon only at high concentrations found following a direct spill into a stream.

Several acute toxicity tests conducted on fish are reported by Fisher and Rosner (1959). A 4-day toxicity study was conducted with *B.t.* on rainbow trout and bluegills in which two groups of ten fish each were placed in water containing *B.t.* at concentrations of 560,000 and 1,000,000 ppb. None of the trout or bluegills died (Fisher and Rosner, 1959). Rainbow trout that were 4 inches long were exposed to *B.t.* at concentrations of 100,000 to 1,000,000 ppb for 14 days. No deaths resulted, nor were symptoms of alimentary or behavioral disturbances evident (Fisher and Rosner, 1959). In a test with juvenile coho salmon (1.6 inches long), *B.t.* was shown to be about 1/30 as toxic as DDT. The test ran for 168 hours with concentrations of 8,000 to 406,000 ppb. The 48-hour median tolerance limit of *B.t.* was about 50,000 ppb (Fisher and Rosner, 1959). In other words, for 48 hours, 50 percent of the fish tested tolerated a *B.t.* concentration of 50,000 ppb with no observable adverse effects.

Other toxicity test results are listed in the chemical profile for *B.t.* contained in the Environmental Assessment Western Spruce Budworm Management in Northeastern Oregon, Appendix 1984 (1984 EA). A summary of these data indicates no reason to suspect impacts upon aquatic fauna other than aquatic lepidopterans and selected dipterans (flies). Aquatic moth species belonging to the family Pyralidae are not known to occur within the area. In a study by Eidt (1985), blackfly larvae (Simuliidae), demonstrated susceptibility to *Bacillus thuringiensis* var. *kurstaki (B.t.k.)* in concentrations of 430 International Units/liter. *B.t.k.* has also been tested and found to be more or less toxic to several species of mosquitos (Krieg and Langenbruch, 1981). Two crustacean species in the genera *Daphnia* and *Cyclops*, and a mayfly species, *Picromerus bidens*, were tested in Eidt's study and shown to suffer no effects from *B.t.k.* Other varieties of *B.t.* have also demonstrated toxicity to some species of mosquitos and blackflies. *Bacillus thuringiensis* var. *kurstaki* is the variety being considered in this analysis.

Unlike chemical insecticide testing which often produces widely varying results, the testing of *B.t.* has proven to be more consistent in its effects upon nontarget organisms. As a result, *B.t.* is used in the East without extensive monitoring programs. The study by Eidt (1985) demonstrating no toxicity to mayfly, stonefly, and caddisfly larvae, and toxicity only in high concentrations (430 International Units/liter) to blackfly larvae, has resulted in a policy change. New Brunswick regulations no longer require stream and lakeside buffers when using *B.t.* field applications where worst-case scenarios project concentrations of less than 4.3 International Units/liter. Therefore, the concentration of 430 International Units/liter represents a value 100 times greater than that which would be expected in a direct application to water.

B.t. treatments in streamsides would pose no threat to aquatic organisms unless a direct spill occurred. Concentrations in streams resulting from normal treatment would be far below the levels that proved toxic to blackfly and mosquito larvae. The adverse effects of spills would be short-term and limited to relatively small stream reaches.

The risk of spills, and subsequent contamination of water with fuel and/or large quantities of *B.t.*, is very low.

Alternative D

The impact on fisheries and aquatic systems is expected to be the same as effects from Alternatives B or C.

Mitigating Measures

Aerial insecticide application near streams and open waater is controlled by State law. In Oregon, State

regulatory agencies have agreed that *B.t.* may be aerially applied parallel to and up to the edges of streams and open water. A variance must be obtained from the Washington State Department of Ecology to apply *B.t* up to the edges of streams in that State.

A buffer zone will be left adjacent to streams, lakes, wetlands, and other waterways when applying carbaryl. This buffer strip must be at least one swath wide.

The following measures will be used to minimize the probability of unintentional adverse affects on water-related resources and nontarget organisms from spills or application errors:

Aircraft spray equipment calibration testing over wetlands or floodplains will be prohibited.

A pilot car will be required during transportation of insecticides or fuel on roads within municipal watersheds.

Helispots will not be located in or adjacent to meadowlands or floodplains.

Wetlands, including lakes and ponds, which are large enough to identify from the air, will not be oversprayed with insecticides. There may be relatively small wet areas that, because of the tree canopy cover, cannot be identified from the air which will be unavoidably but inadvertently sprayed.

Aquatic Toxicity

Fish

Diesel and jet fuels and fuel oils are moderately to highly toxic to fish (based on the toxicity categories of EPA, 1985). Jenkins et al., (1977, as cited in Burks, 1982) studied the acute and chronic toxicity of jet fuels to several fish species. They reported 96-hour LC_{50}'s (static tests) for the Golden shiner (Notemigonus crysoleucas) of 0.68 and 0.94 mg/1 for the jet fuels RJ-4 (a 12-carbon molecule) and RJ-5 (A 14-carbon molecule), respectively. They also reported a 97-day nonlethal concentration for rainbow trout (Salmo gairdneri) of less than 0.03 mg/1 for RJ-4 and 0.04 mg/1 for RJ-5; and a no-effect level for eggs of the flagfish (Jordanella floridae) exposed by continuous flow to RJ-4 of 0.2 mg/1. Reduced hatchability was observed in flagfish eggs from exposure to RJ-5 at concentrations above 0.05 mg/1.

Acute toxicity tests with freshwater fish showing 96-hour LC_{50}'s of greater than 0.19 mg/1 for diesel fuel, and greater than 1.2 mg/1 for No. 2 fuel oil have been reported by EPA (1976, as cited in Department of Energy [DOE], 1983). Tagatz (1961, as cited in Burks, 1982), reported much lower toxicity, with a 48-hour LC50 for No. 2 fuel oil of 125 to 251 mg/1 with juvenile American shad. His reported LC50 is based upon the amount of oil applied to the water surface (nominal concentration), and not the water-soluble fraction; this may account for the apparent lower sensitivity of the shad.

The toxicity of No. 2 fuel oil has been studied for a number of marine fish and invertebrate species. The LC_{50}'s range from 0.81 to greater than 6.9 ppm for marine fish, and 0.21 to 14.1 ppm for invertebrates (Connell and Miller, 1984). The range of toxicity values determined for No. 2 fuel oil with marine species is useful in estimating the range of sensitivities for freshwater species because marine and freshwater species generally have a similar range of tolerance to toxicants (Sprague, 1985).

Irwin (1964, as cited in Burks, 1982) calculated a "ratio of resistance" to allow the ranking of the sensitivities of 57 fish species to oil refinery wastewater. The guppy (*Lebistes Reticulatus*) was least sensitive and was assigned a ratio of resistance of 100. The ratios of resistance for some of the common freshwater fish were as follows: rainbow trout *(Salmo gairdneri*), 34.68; smallmouth bass (*Micropterus dolomieui*), 35.60; northern pike (*Esox lucius*), 37.31; fathead minnow (*Pimephales promelas*), 49.19; largemouth bass (*Micropterus salmoides*), 53.27; bluegill (*Lepomis macrochirus*), 54.10; and channel catfish *(Ictaluras punctatus*), 60.15. This study may be useful in predicting the relative order of sensitivities of these species to diesel fuels and other petroleum products.

Aquatic Risk Analysis

The risk of adverse effects from exposure to insecticides that drift offsite, and accidents, was estimated for the representative aquatic species described previously. Acute toxicity reference values (LC_{50}'s or EC_{50}'s)1used in the analysis were selected for representative species.

In cases where no acute toxicity reference value was available for a representative species, a value was selected using the value of the most closely related species. For fish species, preference was given to toxicity values of other species within the same genus or family. If no toxicity values were available for any member of that family, the lowest value reported for any fish species was used.

To estimate the risk of adverse effects occurring, the selected toxicity reference values were compared to the typical and worst-case estimated environmental concentrations of each insecticide for a body of water 0.61 m (2 ft) deep. The ratio of the EEC to the LC_{50}

(or EC50) is named the quotient value (Q-value). Typical EEC's were based upon typical application rates and a distance of 153 m (500 ft) from the application site to the body of water. Worst-case EEC's were calculated using maximum application rates and a distance of 30.5 m (100 ft) to a water body. EEC's for petroleum distillates were based upon the fraction of kerosene in carbaryl formulations and the amount of diesel oil used as a carrier. The Q-values were compared to the risk criteria proposed by EPA (1986) where the risks of adverse effects to fish or invertebrates are estimated as follows:

Q-value	Risk
EEC/LC_{50} < 0.1	No acute risk
EEC/LC_{50} $\geq$ 0.1 and <0.5	Presumption of risk that may be mitigated
EEC/LC_{50} $\geq$ 0.5	Presumption of significant risk of acute effects
EEC (NOEL or MATC[a]) <1.0	No chronic risk

Results of the Risk Analyses

Acute Toxicity

The results of the risk analysis indicate there is no significant risk of acute adverse effects to any of the representative aquatic species for typical and worst-case exposures resulting from drift (Table IV-XVIII). All Q-values are less than 0.1. Aquatic invertebrates are at slight risk of adverse effects from malathion under worst-case conditions.

The acute risks to some groups of aquatic invertebrates could not be estimated for some of the chemicals because sufficient toxicity information was not available (Table IV-XIX).

Based on the most conservative acute toxicity value, aquatic organisms are at slight risk from the petroleum distillates (kerosene and diesel oil combined) under typical conditions. Under worst-case conditions, aquatic organisms are at significant risk of adverse effects from petroleum distillates (Table IV-XVII).

Fate in the Aquatic Environment

Carbaryl degrades rapidly in water in 1 to 5 days. Carbaryl applied over open water, such as small brooks or ponds, at an initial deposit of 1 ppm or less in a water depth of about 4 inches, may be expected to degrade completely or disappear in 1 or 2 days (Romine and Bussian, 1971; California Department of Fish and Game, 1963; Lichenstein et al., 1966). Results were similar for water treated with Sevin 4-Oil during a gypsy moth suppression project (Willcox, 1972).

Fate in Plants

The low vapor pressure of carbaryl makes it unlikely that it will volatilize from plant surfaces. The susceptibility of carbaryl to photolysis, and its low solubility, minimize the possibility of washoff from plants.

Various field studies have been conducted to determine the persistence of carbaryl residues on plants. Residues of Sevin 4-Oil, applied at 0.75 lb a.i./acre in northeastern forests, were found on foliage 60 days after treatment (Ghassemi et al., 1981). A field study of carbaryl residues on foliage when Sevin 4-Oil was applied at 1 lb a.i./acre, showed the half-life on grass as 8 days, on geraniums as 3 days, on aspens as 8 days, and on Douglas-fir as 4.5 days (Pieper, 1979). This study also reported grass to have the highest percent of residue recovered (89.5 percent). In a field study in India, the half-life calculated for cabbage was 3 days and 3.2 days for eggplants (Mann and Chopra, 1969). The calculated half-life of carbaryl, when applied to runoff on apple leaves at 0.5 and 1.0 lb a.i./100 gal, was 13.33 days with a 90-percent reduction in the average surface residue 31 days after treatment (Sell and Maitlen, 1980). When applied to lemon and orange trees at 11.5 lb a.i./acre, residues were reduced by 83 percent and 94 percent, respectively, by 60 days after treatment, and calculated half-lives were 14 days on orange leaves and 22 days on lemon leaves (Iwata et al., 1979). Dissipation rates 8 days after treatment were 81 to 88 percent for spinach, and 82 to 85 percent for chicory. Tilden and van Middelem (1970) reported the rate of dissipation of carbaryl on plants appears to be independent of the initial concentration. The following allowable and actual carbaryl residues were reported for citrus and soybeans: (1) 10 ppm residues were allowable for citrus, and 2 to 8 ppm were found 5 days after treatment (1 lb/100 gal); and (2) 5 ppm residues were allowable for soybeans with 0.96 ppm found 38 days after application (1 to 2 lb a.i./acre) (Clement Associates, 1978). In summary, although dissipation rates of surface residues do not vary according to initial concentrations, the proposed application rate of 0.5 lb/a.i./acre (8 oz a.i./acre) of carbaryl for the grasshopper control program is lower than any of those reported in the above studies. Therefore, original residues (ppm) should be lower than those reported.

Small amounts of carbaryl may be absorbed by roots and foliage and distributed into plants (EPA, 1984). Higher plants have been found to produce some metabolites that remain in the plant tissue and cannot be removed by the usual extraction procedures (Casida and Lykken, 1969; Dorough and Wiggins, 1969). Injection of carbaryl into bean plants led to production of water-soluble compounds that were stable within the plant (Kuhr and Casida, 1967). Studies on bean and cotton plants showed carbaryl to have a 3- to 7-day half-life (Dorough et al., 1963). The plant systems responsible for these changes may be enzymatic or nonenzymatic, and may catalyze hydrolysis of the carbamate (Casida, 1963).

Although a portion of the metabolites produced in higher plants is water soluble and may enter the bodies of animals when the plants are eaten, these soluble metabolites are quickly eliminated (for example, more than 90 percent elimination after 96 hours in rats) by way of the urine and feces (Casida and Lykken, 1969; Dorough and Wiggins, 1969). Of six known higher plant metabolites administered to rats, five were less toxic than carbaryl. The remaining metabolite was more toxic than carbaryl, but it was noted the metabolite is produced only by a minor metabolic pathway in plants (Wiggins et al., 1970).

Carbaryl is nontoxic to most plants when applied at label rates (Amer, 1965). Carbaryl has been found to injure Boston ivy, Virginia creeper, and maidenhair fern (Union Carbide, 1982), as well as pears, watermelons, and some types of apples (Thomson, 1979). Minor stunting of conifer seedlings has also been observed (Sutherland et al., 1977), and retarded germination of grasses may result from excess dosages of carbaryl (Thomson, 1979). Carbaryl may induce abnormal cell mitosis and meiosis in root tips, but recovery occurs within 48 hours (Amer and Farrah, 1968; Amer, 1965). Seed viability may be increased because of the fungicidal action of carbaryl (Eid et al., 1971).

Biological Uptake

Carbaryl is not subject to significant bioaccumulation in aquatic ecosystems because of its low solubility and low octanol-water partition coefficient (K_{ow} = 230) (Dobroski, 1985). Uptake of carbaryl in fish has been detected, with 95 percent excreted within 8 hours (Tompkins, 1966).

Fish

The LC_{50}'s of carbaryl for a number of aquatic organisms are shown in tables located in Appendix F. The toxicity of the technical formulation is greater than the 49-percent oil dispersion formulation (Sevin 4-Oil). The acute aquatic toxicity of carbaryl is relatively low when compared to other insecticides. Members of the catfish (Ictaluridae) and minnow (Cyrinidae) families are nearly ten times more tolerant of carbaryl than the trout (Salmonidae) family. The toxicity to sunfish and bass (Centrarchidae) is approximately midway in this range.

Acetylcholinesterase depressions (13 to 22 percent) have been observed in brook trout within 24 hours of spraying carbaryl at 1 lb/acre. Levels returned to normal within 48 hours. At the same application rate, Atlantic salmon (**Salmon salar** C.) showed average AChE depression of 20 percent. Levels did not return to normal within 48 hours (Hulbert, 1978; Marancik, 1976).

Invertebrates

Some aquatic insects in the orders Plecoptera (stoneflies) and Ephemeroptera (mayflies) are highly sensitive to low levels of carbaryl. Trichoptera (caddisflies) and Diptera (true flies) are also sensitive to carbaryl. There may be a 50- to 100-percent reduction in aquatic insect populations in treated streams and ponds (Burdick et al., 1960). Mount and Oehme (1981) found that applications of 1.25 pounds of carbaryl per acre were not directly toxic to fish, but food items were reduced by 97.2 percent. LOTEL (1975) reported that in a stream treated with 1 lb carbaryl/acre, each sampling station recorded a residue of at least 40 ppb and a peak residue of 80 ppb. The biological impact was indicated by increased drift of dead and dying stoneflies, mayflies, caddisflies, and true flies.

The effects of 2 consecutive years of spraying on other aquatic organisms appear similar to those observed in areas treated just once (Trial, 1978, 1979; Courtemanch and Gibbs, 1978). These effects include loss of stonefly species from individual streams and altered generic assemblages for an indefinite period (Trial, 1978, 1979). A study of buffered streams by McCullough and Stanely (1980) during the 1979 Maine spruce budworm spray project indicated that benthic invertebrate fauna were not adversely affected. Also, the numbers of drifting invertebrates were substantially lower than in previous years. The long-term impact appears to be a function of species susceptiblity and recolonization ability. Two consecutive years of spraying with carbaryl reduced populations of stonefly and susceptible mayfly genera to near zero.

Carbaryl (Sevin 4-Oil) was applied to woodland ponds in Maine at a rate of approximately 1.85 lb. a.i./acre (.84 kg a.i./acre). Caddisfly populations were temporarily reduced. Most severely affected were the

amphipods (*Hyallela azteca*), which were nearly reduced to zero. This group failed to recolonize in some ponds for up to 30 months after spraying (Gibbs et al., 1984).

Aquatic Plants

Carbaryl was nontoxic to a species of fresh-water algae at 1.0 ppm. The growth rate of the algae actually increased after exposure to carbaryl; this was thought to be a result of the increase in available nitrogen (an important plant nutrient) from the degradation of carbaryl (Stadnyk et al., 1971). An increase in algae growth rate after exposure to carbaryl also was reported by Murray and Guthrie (1980).

Cultural Resources

Alternative A - No Action

Under this alternative, there would be no change from the effects expected due to ongoing Forest management operations.

Alternatives B, C, and D

The only ground-disturbing activity to be encountered under these alternatives is the possible establishment of new heliport sites within forested areas.

Mitigating Measures

Before any ground-disturbing activities occur, previously undisturbed and unsurveyed areas will be examined by qualified personnel for the presence of cultural resources. Appropriate protection measures will be taken for any cultural resource sites discovered to ensure cultural information is not lost. The State Historical Preservation Officers in Oregon and Washington would be consulted on each proposed site.

Wilderness

The Forest Service Manual defines several objectives in regard to management of insects and plant disease in Wildernesses (FSM 2324.1):

1. "To allow indigenous insect and plant diseases to play, as nearly as possible, their natural ecological role within wilderness.

2. To protect the scientific value of observing the effect of insects and diseases on ecosystems and identifying genetically resistant plant species.

3. To control insect and plant disease epidemics that threaten adjacent lands or resources."

The life cycle of the western spruce budworm suggests the lack of treatment in Wildernesses does not pose a threat to non-Wilderness (i.e., adjacent) lands nor threaten the resources within Wildernesses. Therefore, in the majority of instances, natural processes would be allowed to continue without control in Wildernesses

In situations where spruce budworm infestations in Wildernesses might affect adjacent non-Wilderness resources, treatment would be evaluated on a case-by-case basis.

Population levels would be monitored "in a manner that preserves the Wilderness character of the area."

If control measures were necessary in specific cases to prevent unacceptable damage to lands adjacent to Wildernesses, treatment measures must have the least impact on the Wilderness resource and be compatible with Wilderness management objectives.

Alternative A - No Action

Since the western spruce budworm is an indigenous component of the forest environment, any effects to forested areas during a naturally occurring budworm outbreak are, by policy, an acceptable part of the natural ecology.

Alternatives B, C, and D

Many people would be concerned about the use of any insecticide within National Forest Wildernesses since application of insecticides is not considered a naturally occurring event. Insecticide application would interfere with the natural processes which are a key part of the Wilderness resource. Also, the application process would detract from the solitude and primitive recreation experience offered in Wildernesses.

Fire And Fuels

Fire Management

The goal of fire management is to maximize fire effects which enhance long-term forest and watershed management, and to minimize those effects considered to be detrimental. The Forest Service devotes much effort to fire prevention and suppression efforts thereby reducing the potential of large fires.

Fire History

Weather determines the amount of moisture that is contained in fuels. The amount of moisture in fuel

particles determines how easily a spark will start a fire and how rapidly the fire will grow.

Fuels range in size from small twigs and dead grass to large logs and duff. Small twigs and grass change moisture content quickly when changes in daily relative humidity occur. Small fuels are typically at their driest point during mid-day when relative humidities are low and temperatures are high.

Decaying logs and duff contain small fuel particles (needles, twigs, etc.) on the surface which can ignite easily. Yet these logs and duff do not burn readily without prolonged drying periods of days or weeks. Summers in the Pacific Northwest frequently have dry periods long enough to reduce moisture levels in large logs, duff, and even live vegetation to a point where they will burn readily and may continue to burn for long periods of time.

Fires in the Pacific Northwest tend to be intense, stand-replacing events. A mixture of species is often the result of fires. Postfire plant succession is quite variable, and any combination of fire intensity can occur in any stand type, depending upon the key factors of fuels, weather, and topography. Postfire plant community diversity will reduce the susceptiblity to spruce budworm infestations.

The interaction between forests and fire in the Pacific Northwest is complex. Light fires, those which are less intense and remain on the ground, do not necessarily kill trees. In fact, such fires may remove fuel, thereby preventing the occurrence of a catastrophic fire. Intense fires, especially those burning in heavy fuels, are often quite destructive and may kill all trees in a stand.

Fuel hazard levels in lightly defoliated areas remain low where only scattered trees were killed. High hazard levels now exist on sites where a substantial number of trees have been killed. When combined with a drought or high winds, this fuel hazard could contribute to an intense catastrophic fire.

Fuel reduction reduces the intensity of wildfires that could occur in the future.

Limbs, twigs, and needles on the ground increase the rate of spread and intensity of any fire that starts in the area until the fuel decays. Complete decay of these fine fuels takes approximately 10 years. If fires occur in the large, heavy fuels which are abundant in severely defoliated areas, fire suppression would be very difficult, especially the construction of firelines made by hand. The presence of large trees on the ground will reduce the effectiveness of fire suppression efforts, depending upon the size and quantity of large trees left in place. Ongoing salvage logging of mortality and the reduction of woody debris, will, in time, reduce fuel hazards to low levels.

Effects on Wildfire Potential

Fire is a valuable tool in the management of conifer ecosystems. There are also many positive ecological effects of fires (whether wildfires or slash burns), depending upon the size, location, and intensity of the fire. One potential benefit is the rapid production of forage and cover for many wildlife species; another is duff reduction and site preparation for planting tree seedlings.

Fire can also be a destructive force. Large, intense fires can adversely affect soil, and subsequently, water quality by removing most of the surface vegetation and duff layer that protects the soil from erosion. Soil erosion, if located near watercourses, can adversely affect water quality. The impact of wildfire on water quality depends upon where the fire is, how big it is, and how intensely it burns. In addition, high intensity fires can greatly reduce forage and cover for certain wildlife species for long periods of time. Sites which undergo low intensity fires usually produce forage and cover much more rapidly.

When timber stands are defoliated, small quantities of highly flammable fuels are produced immediately following defoliation events. Small twigs and needles accumulate on the forest floor at an accelerated rate following defoliation. This additional material does not normally add significantly to total fuel loading. When severe defoliation occurs several years in a row, hundreds of acres in an area can experience mortality exceeding 90 percent of the stand. These larger areas of dead trees will experience significantly higher fuel loading when the dead trees begin to fall. The fallen trees complicate suppression efforts. Fire intensity is increased in areas with heavy concentrations of fallen trees. Line construction is slowed significantly when firelines are constructed in areas with heavy fuels.

The No-action Alternative has little impact on fuel loading in areas where only scattered mortality occurs. The total fuel loading does not change significantly. Severe defoliation that results in areas of continuous mortality will experience high fuel loading. Fireline construction will be extremely slow, and firefighter safety will be a concern due to many falling snags and fire intensity. Snags, large logs, and beds of needles form an accumulation of fuels on the forest floor. Forest fires result when this buildup of fuel is coupled with dry summers and lightning, or other sources of ignition.

Alternatives B, C, and D will reduce or eliminate the short-term potential for heavy fuel buildups. Only

scattered mortality will occur. Line construction will not be slowed, and fire intensity will not increase.

All alternatives have cumulative effects on fuel levels by adding amounts of fuel to existing fuel loadings. The No-action Alternative has the most significant cumulative effect since mortality add significantly to existing fuel levels. The cumulative effects of Alternatives B, C, and D should not be significant when added to existing fuel loadings. Cumulative effects have an impact on suppression capabilities as well. As fuels are added to existing fuel beds, suppression difficulty increases.

There are no conflicts expected between the alternatives and other plans and policies for fire and fuels management.

Recreation

National Forests in the Pacific Northwest provide recreational opportunities for millions of users every year. People seek enjoyment in National Forests. Opportunities for recreation are as diverse as the land where activities take place. Recreation experiences vary from physical challenges and solitude in pristine Wildernesses, to social gatherings in camp and picnic facilities.

Traditional uses such as camping, picnicking, hunting, fishing, and hiking,take place on all National Forests. Many activities have been popular as long as public lands have been available for those uses. The recent popularity of other recreation pursuits, such as cross-country skiing, wind surfing, and bicycle touring, have created new opportunities for people to enjoy National Forests. As the availability of leisure time increases and the pressures of urbanization become more intense, the need to enjoy the natural scenery in National Forests will become increasingly important.

Recreation takes place in the absence of other demands on our time. The availability of leisure time for recreation means there are no commitments or products to produce. Outdoor recreation in a natural setting provides many social and psychological benefits, including physical exercise, as well as mental stimulation, relaxation, refreshment, and enjoyment. Nature also provides a sense of stability, internal harmony, and balance, according to laws not subject to human manipulation. National Forests offer an opportunity to escape from urban life and social pressures, find order and purpose in our lives, review our sense of values, and strengthen family ties.

Visual quality in recreational areas may be directly and adversely affected by a western spruce budworm infestation when tree damage becomes significant. This has an impact, particularly in recreation areas and travel corridors. Short-term effects include browning of foliage and tree growth loss. Long-term cumulative effects are tree mortality and spike tops (dead tops) in poles and mature trees. Recreation areas in the host-type will become less desirable, reducing the quality of the recreation experience for many years. Some recreation users will no longer enjoy activities on National Forests due to this loss in scenic quality.

Mitigating Measures

The action alternatives would mitigate additional loss of visual quality due the western spruce budworm outbreak.

Visual Resources

The American people are concerned about the quality of their visual environment. The "visual landscape" is a basic resource, to be "treated as an essential part of and receive equal consideration with the other basic resources of the land".

"The majority of the recreation-oriented people who visit the National Forests have an image of what they expect to see. Such an image or mental picture is generated by available information concerning a particular area and the person's experience with that or similar areas. The image produced represents the knowledgeability, expectedness, romanticism, and emotionalism associated with features within the area. Obviously, several images may exist simultaneously, even within a single individual, and yet a particular geographic region tends to have an identifiable image.

Although studies of people's images of forest areas result in varied responses from one geographic region to another, one factor generally remains constant. People expect to see a naturally appearing character within each general region.

Esthetic concern varies among National Forest users. Those people most concerned about esthetics are those who are in an area because of, or have a major interest in the scenic qualities, e.g., recreation area, residents, and travelers.

The visual impacts of spruce budworm defoliation increase as the duration of view increases beyond a quick glance. Examples are those areas seen from vista points, visitor centers, and scenic highways. The visual impacts of spruce budworm activity become

more important as the actual or potential number of viewers increases.

All landscapes have a definable character and those with the greatest variety or diversity have the greatest potential for high scenic value.

Landscapes vary in form, line, color, and/or texture. Spruce budworm defoliation has the greatest impact on color and texture. Each landscape unit has its individual capacity to accept alterations in color and texture without losing its inherent visual character. The visual impact of defoliation increases as the amount of landscape color and texture alteration increases.

Visibility and clarity of detail are often functions of viewing distance. The visual impact of defoliation usually increases as viewing distance decreases. Distance zones are divisions of a particular landscape being viewed. They are used to describe the part of a characteristic landscape. The three distance zones are:

Foreground

The limit of this zone is based upon distances at which details can be perceived. Normally in foreground views, the individual boughs of trees form texture. Foreground will usually be limited to areas within 1/4 to 1/2 mile of the observer.

Middleground

This zone extends from the foreground zone to 3 to 5 miles from the observer. Texture normally is characterized by the masses of trees in stands of uniform tree cover. Individual tree forms are usually only discernible in very open or sparse stands.

Background

This zone extends from middleground to infinity. Texture in stands of uniform tree cover is generally very weak or nonexistent. In very open or sparse timber stands, texture is seen as groups or patterns of trees.

Sensitivity Levels are a measure of people's concern for the scenic quality of the National Forests.

Sensitivity levels are determined for land areas viewed by those who: are traveling through the Forest on developed roads and trails; are using areas such as campgrounds and visitor centers; or are recreating at lakes, streams, and other water bodies. Three sensitivity levels are defined, each identifying a different level of user concern for the visual environment.

Level 1 - Highest Sensitivity

Level 2 - Average Sensitivity

Level 3 - Lowest Sensitivity

Level 1

Sensitivity Level 1 includes all seen areas from primary travel routes, use areas, and water bodies where, as a minimum, at least one-fourth of the Forest visitors have a major concern for the scenic qualities. Examples are all areas seen from primary roads, primary trails used by hikers and horsemen, and primary use sites within National Parks, National Recreation Areas, Wildernesses, and other dedicated Wild Areas.

Sensitivity Level 1 also includes all seen areas from secondary travel routes, use areas, and water bodies where at least three-fourths of the Forest visitors have a major concern for the scenic qualities

Level 2

Sensitivity Level 2 includes all seen areas from primary travel routes, use areas, and water bodies where fewer than one-fourth of the Forest visitors have a major concern for scenic qualities.

Level 2 also includes all seen areas from secondary travel routes, use areas, and water bodies where at least one-fourth, and not more than three-fourths, of the Forest visitors have a major concern for scenic qualities.

Level 3

Level 3 includes all seen areas from secondary travel routes, use areas, and water bodies where less than one-fourth of the Forest visitors have a major concern for scenic qualities. (Level 3 does not include any areas seen from primary routes or areas.)

Alternative A - No Action

The impact of continued defoliation on visual quality and the Forest users' experience will be greatest in the areas with severe defoliation. These areas will experience extreme color and texture changes for up to a decade or more. The most sensitive of these areas will be the foreground zones that are seen by the greatest number of visitors. This drastic change in color and texture occurs over several years.

The most severe cases of defoliation result in widespread mortality and top-kill, and reduce the value of the landscape to Forest user's. Recreation use could decline as a result of continued defoliation, with a corresponding impact on the recreation economy.

The long-term effect of severe defoliation would result in the creation of a more diverse forest with tree species resistant to spruce budworm attack. This

would result in a landscape less susceptible to change in color and texture from spruce budworm activity. This process of long-term change in tree species would take several decades.

The cumulative impact of the No-action Alternative will be the addition of acres of defoliation and visual change that occurs each year until the population is reduced by natural events.

There are conflicts with this alternative, and other plans and policies for the management of the visual resource. Conflicts result when landscape quality management objectives cannot be met due to severe defoliation impact.

Alternatives B, C, and D

Short-term protection of foliage by using *B.t.* or carbaryl reduces the change in color and texture that occurs on the landscape but does not eliminate it. Color and texture changes are still slightly detectable. Protection of foliage reduces the cumulative mortality and top-kill. The landscape will maintain a more natural-appearing character. Low levels of spruce budworm defoliation will make slightly visible impacts on color and texture. Only slight reductions in recreation user numbers would be expected when foliage protection is provided at intervals sufficient to maintain the natural appearance. The economic impacts should be low. Specific distance zones and sensitivity areas can be selectively protected from severe defoliation.

The long-term effect of protecting foliage would result in the maintenance of a forest with tree species susceptible to continued defoliation. This would result in a landscape more susceptible to change in color and texture.

Notification of a pending spray project, instructing the public on safety precautions to take while visiting a project area, will cause concern and result in a short-term loss of recreation opportunity for those individuals electing not to visit the project vicinity.

The cumulative effect of implementing Alternatives B, C, or D will be the cumulative annual reduction of acres severely defoliated.

There are no conflicts expected between these alternatives and other plans and policies for management of the visual and recreation resource.

Mitigating Measures

The action alternatives would mitigate additional loss of visual quality due to the western spruce budworm outbreak.

Human Health

A risk assessment was done to assess the risks to human health of using the chemical insecticide carbaryl and the biological control agent, *Bacillus thuringiensis (B.t.)* for controlling western spruce budworm in Region 6. That risk assessment is Appendix F of this EIS. The risk assessment also assessed the human health risks of malathion and acephate; however, those two insecticides are not discussed here because they were eliminated from detailed consideration as spruce budworm insecticides.

The risk assessment also addressed the human health risks of a number of chemicals associated with the application of the insecticides and *B.t.* Because carbaryl is commercially formulated (as Sevin 4-Oil) with kerosene, and because diesel oil is used as a carrier in the application of Sevin 4-Oil, the risks of these two petroleum distillates were analyzed. The risks were evaluated for the two products separately and combined because of their similarity and use in the same mixture. (Petroleum distillates are listed by EPA as inert ingredients of no toxicological concern.) The risk assessment also looked at the *B.t.* formulation ingredient, mineral oil, (N-nitrosocarbaryl), a carcinogenic metabolic product of carbaryl that may form in the stomach after oral exposures; malaoxon, a metabolic product of malathion; and methamidophos, a toxic degradation product of acephate. The latter two chemicals are not discussed here for the same reasons stated above.

The risk assessment examined the potential health effects to all persons who might be exposed to the insecticides, and associated chemicals, as a result of activities related to spruce budworm spray programs. The two groups of people considered at risk were worker personnel directly involved in application of the insecticides and the public. The two groups included forest visitors and residents, who could be exposed to drifting insecticide spray droplets by touching sprayed vegetation, or by consuming contaminated food items or water.

The analysis used the methodology of risk assessment generally accepted by the scientific community. In essence, the risk assessment estimated doses people may get from applying the insecticides (worker doses) or from being near an application site (public doses), then compared those estimated doses with doses shown to cause no observed effects in tests on laboratory animals.

Structure of the Risk Assessment

The risk assessment employed three principal analytical elements: hazard analysis, exposure analysis, and risk analysis. The relationship among these components is illustrated in Figure IV-I.

Hazard Analysis

The hazard analysis identified the toxic properties of *B.t.*, and of each chemical insecticide originally considered for the program, in a thorough review of available toxicological studies. Scientific uncertainty about the results of these studies was considered in determining their usefulness in characterizing the toxicity of the material in question. When no studies were identified for a particular toxicity endpoint, for example, mutagenicity, these data gaps were identified and a worst-case analysis was conducted for this endpoint. The hazard analysis is presented in Appendix F.

Exposure Analysis

The risk assessment analyzed a range of possible exposures--from realistic to extreme--using three types of scenarios: (l) typical application scenarios (routine-typical) to estimate worker and public doses that may reasonably be expected to occur during routine operations, (2) worst-case application scenarios (routine-worst case) to give very high dose estimates not likely to be exceeded except in the case of an accident, and (3) accident scenarios to estimate public and worker doses from exposure to spray mix or concentrate, directly or in spills into drinking water.

To establish the most appropriate scenarios, the exposure analysis considered the characteristics of the spraying operations (including application methods, application rates, size and configuration of spray areas, project design features, and mitigation measures), the human populations likely to be exposed, and the routes of exposure for humans in routine operations and as a result of accidents.

Insecticide Spraying Operations

The insecticides examined in the risk assessment are applied aerially, using fixed-wing or helicopter aircraft, or by backpack sprayer for seed orchards or campgrounds. The size of the program may vary in any given year. A total of 25,000 acres may be sprayed in 1 day, but no more than 5,000 acres in a single watershed. The risk assessment contains further details about spray operations.

Routine Exposure Scenarios

For members of the public, including forest visitors and nearby residents, the routine-typical and routine-worst case exposure scenarios estimated doses from the three principal routes. Oral doses were assumed to come from eating meat, fish, berries, garden vegetables, or drinking water with insecticide residues. Dermal doses came from vegetation contact and drift exposure, and inhalation doses from drift exposure. Cumulative exposures to hypothetical hunters and fishermen from several exposure routes also were calculated. Worker exposures were estimated for pilots, mixer/loaders, aerial and ground-based observers, card checkers, and efficacy evaluation team members. Cumulative lifetime doses were estimated for the analysis of lifetime cancer risk by using information on average and maximum treatment days per year and on average and maximum number of years exposed for workers and for the public.

Accident Exposure Scenarios

A number of accident scenarios also were analyzed including direct aerial application of insecticide on a person, spills of concentrate or insecticide mix on workers during mixing and loading, spills of insecticide into drinking water supplies, and direct spraying of garden vegetables.

Special Case Analyses

Two special case analyses were done to evaluate the risk from hypothetical circumstances of exposure thought possible in spraying of a forested watershed for budworm suppression. The first special case involved estimating exposures for persons drinking water from reservoir feeder streams and from a reservoir itself immediately after rainfall runoff contaminates the streams and reservoir. The runoff in each feeder stream is assumed to come from one of three 5,000-acre spray blocks on The Dalles watershed which are sprayed in sequence on 3 consecutive days. A rainstorm follows on the fourth day. The second special case analysis involved estimating exposure from consuming crops that have been irrigated with contaminated reservoir water.

Risk Analysis

The risk of acute and chronic health effects was evaluated by comparing estimated doses to no-observed-effect-levels (NOEL's) in laboratory animal studies, using a calculated margin of safety (MOS). A benchmark risk value of 100 was used to assess the likelihood of effects. Risk increases as the

estimated dose approaches the laboratory toxicity level; that is, as the MOS decreases.

The risk of cancer at a given level of exposure, based upon the estimated average daily exposure over a 70-year lifetime, was derived for each insecticide from a cancer potency value based upon laboratory animal data on tumor incidence at increasing dose levels. The risk of cancer was calculated for an estimated lifetime dose for various categories of people who may be exposed to insecticides through various routes.

The risk of heritable mutation was evaluated based upon the weight of evidence from available test data on bacteria, yeasts, plants, mammalian cells in culture, and whole animals. When no test data were available for an insecticide, a worst-case assumption was made that the insecticide is mutagenic, and that risk is then based upon the insecticide's estimated cancer risk. This approach, discussed in detail in the risk assessment, assumes that genotoxic agents would be detected as carcinogens from lower exposures than would be required to induce heritable damage in germ cells.

Risk to more highly sensitive individuals, such as the aged or children who may be affected at extremely low exposure levels, was based on the likelihood of a sensitive individual being exposed.

Risks to human health from the use of *Bacillus thuringiensis* were evaluated based upon the available evidence of toxicity of this biological pesticide in studies of exposed humans and laboratory animals. An MOS value is calculated for inhalation and oral *B.t.* exposures. However, these MOS's may not be appropriate in the case of *B.t.* since much of the rationale involving MOS is derived from known genetic differences in chemical metabolism, DNA repair, detoxification of molecules, and excretion of metabolites, none of which applies to *B.t.* *B.t.* effects on reproduction are not known, so no MOS for those effects scould be calculated. In addition, the *B.t.* analysis does not take into account infectivity; that is, illness caused by the vegetative stage of the *Bacillus* life cycle.

Data Gaps and Uncertainties

There were a number of data gaps and areas of uncertainty identified in the risk assessment. In each of those areas, a conservative approach was used or a worst-case analysis was done that tended to increase the estimates of risk to err on the side of safety.

Data Gaps

The information data gaps, included:

Field studies on exposure to workers.

Information on public exposure.

Field data on residue levels in plants and animals.

Mutagenicity study data for carbaryl (DNA damage.)

Toxicity information on the cumulative effects from exposure to forestry-use insecticides, other pesticides, and/or other chemicals.

Toxicity, infectivity, and exposure information for *B.t.* (var. kurstaki) to supplement the data from the history of its use.

These information gaps are important in deciding the best alternative for action; however, the cost of obtaining this information is an important consideration.

The overall costs for conducting studies to fill the data gaps is considered exorbitant for the limited funds available. In addition, the time necessary to perform and evaluate most of these tests is more than 2 years, and would seriously delay making decisions about managing western spruce budworm. Many of the desired toxicological studies have already been requested by EPA, and the results of these studies will be considered when they become available. In addition, ongoing research and monitoring programs to examine various aspects of insecticide treatment will continue, and these results will be considered as they become available.

Because the cost of filling the data gaps is considered exorbitant, a worst-case analysis was conducted for those areas where information is unavailable, or where there is uncertainty. The worst-case scenarios involving routine insecticide application operations consist of combinations of parameters, as treatment unit size, duration of exposure, application rate, application equipment, and meteorological conditions, that give the highest reasonable exposure value. Extreme exposures due to accidents were also evaluated, including those that could result from direct spills of concentrate on workers' skin, the direct spraying of an individual, and contamination of a public drinking water supply by an insecticide spill.

The worst-case analysis for mutagenicity assumed the insecticide could cause heritable mutations. The risk of heritable mutations was assumed to be no greater than the risk of cancer.

The worst-case analysis for insecticides that had either positive cancer studies, or for which there is scientific uncertainty, assumed these chemicals could cause cancer. A conservative cancer potency value for a chemical was computed by using the highest rates of tumor formation found in the available animal studies. A conservative model for estimating human cancer

rates from tumor rates in laboratory animals was also used.

EPA has identified the data gaps shown in Section 2, Table 2-11, of the risk assessment located in Appendix F, in accordance with the registration guidelines under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended. Although there are data gaps or areas of uncertainty for some of the insecticides in this risk assessment, there is a large body of existing data useful for predicting the behavior and toxicity of these insecticides, including the following:

- Worker exposure studies with EPN (ethyl p-nitrophenyl thionobenzene phosphate) insecticide.
- Studies on drift of the insecticide trichlorfon.
- Residue information for the insecticides in plant and animal tissues.

Dealing with Uncertainties in the Risk Assessment

A number of approaches were used to deal with uncertainties in data or methods used to evaluate risks. First, in evaluating risks to human health based upon laboratory animal studies, a benchmark level of 100 was

established to allow for uncertainty in extrapolating from the no-observed-effect levels (NOEL's) in laboratory animals to levels deemed acceptable for humans. The generally accepted uncertainty factors (NRC, 1986) for establishing the benchmark were 10 for moving from animals to humans (between species variation) and another 10 to account for possible variation in human responses (within species variation). This 10 times 10, or hundredfold, uncertainty benchmark means the laboratory NOEL dose reduced 1 hundredfold would normally be considered an acceptable dose for chronic exposure. In this risk assessment, a margin of safety (MOS) or "hazard level to exposure level" ratio was calculated for each estimated dose by dividing the animal NOEL by the estimated dose. The computed MOS was then compared to the benchmark level of 100 to evaluate the risks of toxic effects.

Second, the analysis compared doses that may occur perhaps a few times in a lifetime (accidental worker doses and all public doses) to dose levels of the chemical that produced no ill effects in laboratory animals exposed every day of their lives. This led to an exaggeration of the risks of these infrequent doses.

Third, to assess the risks of cancer (because they are assumed to pose some risk even at extremely low doses), a different approach was used. A cancer potency value (the probability of developing tumors at increasing dose levels) was taken from a laboratory animal study and multiplied by an estimated human lifetime dose to estimate human cancer risk. The analysis assumed some level of risk even at extremely low doses, and the cancer potency was based on the highest level of tumor incidence in any animal study.

Finally, the methods of estimation of human doses likely to occur from insecticide use tended to overestimate doses to err on the side of safety. Workers are likely to be exposed routinely, but standard safety practices and protective clothing should reduce their actual dose levels below those estimated in this analysis. No member of the public is likely to receive as high a dose as estimated in this risk assessment. Normal safety practice and the remoteness of most treated areas limit the possibility of the public's receiving any dose at all. In the estimates of public doses no insecticide degradation on surfaces or in food and water was assumed to occur, and the public were not assumed to wash themselves or their food items after a spraying.

Risk Assessment Results

Hazard Profiles

This section summarizes the toxic properties of carbaryl, diesel oil, kerosene, and *Bacillus thuringiensis*. Complete toxicity discussions are given in Appendix F, Section 2. Table IV-I lists the toxicity reference values for the chemicals and *B.t* used in the quantification of risk. Mineral oil, a formulation ingredient in *Bacillus thuringiensis*, is not an inert ingredient of concern and is not addressed here. The hazards associated with NI-nitrosocarbaryl, a metabolic reaction product of carbaryl, are presented in this section.

The toxicity of carbaryl to laboratory animals, humans, wildlife, and aquatic species is described in detail in the background statements prepared for the Animal and Plant Health Inspection Service (APHIS) by Roy F. Weston, Inc. (Dobroski, 1985; Dobroski and Lambert, 1984; Lambert, 1985). Most toxicity data presented for *Bacillus thuringiensis* was obtained from a background statement prepared for the Forest Service by Mitre Corp. (Sassaman, 1987). Toxicological data for diesel oil and kerosene was obtained from a background statement prepared by Labat-Anderson Incorporated.

Carbaryl

Acute, Subchronic, and Chronic Toxicity

Carbaryl has been tested in human volunteers at doses ranging from 0.06 mg/kg to 2.8 mg/kg. The highest dose caused epigastric pain and sweating. Depression in resorption of amino acids was seen at 0.13 mg/kg; no effects were seen at the 0.06 mg/kg dose. A human-reference dose of 0.1 mg/kg/day for chronic oral exposure was based on a 2-year rat study with a NOEL of 9.6 mg/kg/day. The systemic NOEL used in this risk assessment was 10 mg/kg/day (9.6 rounded off) based on the rat study. A systemic NOEL of 1.8 mg/kg/day, seen in a 1-year dog study, was not used for this analysis because of the differences in metabolism of carbaryl between dogs and humans. The carbaryl acute oral LD_{50} in rats is 270 mg/kg. This dose is used for evaluation of the effects of high accidental doses.

Reproductive/Developmental Toxicity

Carbaryl is teratogenic in many test species, with lowest NOELs found in dogs, but again the dog effects are not assumed to extrapolate to humans. The reproductive/developmental NOEL used in this risk assessment was 20 mg/kg/day based on a study in monkeys.

Carcinogenicity

Despite speculation that carbaryl could combine with nitrite compounds to form a carcinogen (N-nitrosocarbaryl) under acidic conditions similar to those found in the human stomach, the majority of studies examining the carcinogenic potential of carbaryl have been negative. A preliminary report by the Carcinogen Assessment Group of EPA concluded there was no significant increase in the incidence of tumor induction among treated animals relative to control animals (EPA, 1988v). The review of 10 chronic toxicity, studies and the absence of significant tumor incidence at 400 ppm in rats and mice, has provided sufficient evidence for EPA to conclude "that carbaryl is not oncogenic in experimental animals" (EPA, 1988v).

N-nitrosocarbaryl has been characterized as a mutagen and a carcinogen based on positive laboratory studies (Eisenbrand et al., 1976; Elespuru and Lijinsky, 1973). Theoretically, it is possible that human exposure to N-nitrosocarbaryl could occur from the simultaneous dietary consumption of carbaryl (in food) and sodium nitrate (a food additive) even though the formation of N-nitrosocarbaryl under these conditions has not been documented (Cranmer, 1986). N-nitrosocarbaryl could cause cancer in the stomach or on the skin if it could form in the environment as a result of carbaryl application. However, literature shows that N-nitrosocarbaryl can form only under conditions similar to those found in the human stomach--not in the air or on the skin. Thus, cancer risk from N-nitrosocarbaryl was considered only for oral exposure in the risk assessment. Tumor results from chronic gavage studies with rats exposed to N-nitrosocarbaryl were used to calculate a cancer potency and to determine a potency for humans (Lijinsky and Taylor, 1976; and Lijinsky and Schmal, 1978, as cited in USDA, 1985). The cancer potency was 1.35×10^{-1} per mg/kg/day at the 95-percent upper confidence level. One percent of carbaryl was assumed to be converted in the stomach to N-nitrosocarbaryl. In this analysis, the cancer potency for N-nitrosocarbaryl was assumed to be linear, and was multiplied by 0.01 to estimate the cancer potency of carbaryl.

Mutagenicity

The reproductive effects assessment group of EPA concluded that data from mutagenicity studies indicate that carbaryl does not act as a potent mutagen and can be classified as a weak mutagen (EPA, 1988v). EPA has concluded that carbaryl does not pose a mutagenic risk, because only weak mutagenic responses have been measured and there is no evidence demonstrating the ability of carbaryl to reach germinal tissue; hence, germ cells should not be affected (EPA, 1988v).

Diesel Oil

Acute, Subchronic, and Chronic Toxicity

Based on an acute oral LD_{50} of 9 mL/kg (7,380 mg/kg), diesel oil can be classified as a very slightly toxic compound. A single dermal diesel oil exposure to rabbits resulted in a rating of "extremely irritating" based upon a score of 6.82 (on a scale of 1 to 10), although the irritation may have been caused by additives to the diesel oil for use in internal combustion engines. Diesel oil was nonirritating in primary eye irritation studies. A subacute 3-week dermal study of eight rabbits resulted in an average weight loss of 0.38 kg at the dose level of 4 mL/kg (3,280 mg/kg), and an average weight loss of 0.55 kg with a 67-percent mortality rate at the dose level of 8

mL/kg (6,560 mg/kg). The systemic NOEL for diesel oil used in this risk assessment was 7.38 mg/kg/day on the rat oral LD50 divided by an uncertainty factor of 1,000.

Reproductive and Developmental Toxicity

An inhalation teratology study in which rats were exposed to 101.8 ppm or 401.5 ppm (5.09 or 20.075 uL/kg) of diesel fuel on days 6 through 15 of gestation did not result in any significant teratogenic effects (Mecler and Beliles, 1979). The reproductive NOEL for diesel oil used in this risk assessment was 751 mg/kg/day based upon the above inhalation teratology study in rats.

Carcinogenicity

The carcinogenic potential of kerosene is similar to that of diesel oil since the same substances (BaP and benezene) are responsible in both cases. Kerosene's carcinogenicity is assumed to be the same as that of diesel oil.

Mutagenicity

Kerosene was nonmutagenic both with and without metabolic activation in the Ames bacterial and the mouse lymphoma assays (Conaway et al., 1982). Kerosene also was nonmutagenic in the rat cytogenetic bone marrow assay (Conaway et al., 1982). However, because it contains polycyclic aromatic hydrocarbons (PAH's), as diesel oil does, it is assumed to present a mutagenic risk in this risk assessment.

BACILLUS THURINGIENSIS

Acute, Subchronic, and Chronic Toxicity

No deaths were reported among mice when *B.t.* was administered orally at 0.3 and 1.5 x 10^6 spores per gram (Kimura 1970, as cited in Sassaman, 1987). The toxin in this formulation was not specified. Hernandez and Mclean (undated, as cited in Sassaman, 1987) administered *B.t.* spores to rats in the feed for 1 day. No deaths, adverse effects on body weight gain, or abnormalities in blood counts were observed among the treated animals during a 13-day observation period. The test material in this study may have contained beta-exotoxin as a toxic agent.

No irritation was observed 3 days after a 20-percent suspension of Dipel was applied to either shaved unabraded or shaved abraded skin of the rabbits (Kimura, 1980 as cited in Sassaman, 1987). Skin irritation was observed in the form of erythema and eventual dry skin and sloughing, leaving a smooth, hairless treatment area following application of Dipel 4L to the skin of rabbits at 7,200 mg/kg in an acute dermal toxicity study (Abbott, 1986, cited in Sassaman, 1987). No mortalitities were observed among an unspecified number of mice or rats 7 days after they were exposed to an aerosol of a 20-percent suspension of Dipel for 10 minutes (Kimura, 1970, as cited in Sassaman, 1987). No acute eye irritation was observed in rabbits following ocular instillation of 0.1 ml of a 10-percent suspension of Dipel (Kimura, 1970, as cited in Sassaman, 1987).

In a 13-week Dipel feeding study conducted by Olson and Kwapien (1973, as cited in Sassaman, 1987), 10 rats per group were administered 0.84 mg/kg for 1 week, then 8.4 mg/kg for 12 weeks (Group 1); and 8.4 mg/kg for 1 week, then 8,400 mg/kg for 12 weeks (Group 2). A third group served as the untreated control group. No significant findings were observed in hematology, clinical chemistry, or urinalysis evaluations. In addition, there were no abnormal findings in the gross pathology or histopathology evaluations.

Biotrol was administered in the diet to groups of 20 rats at dietary levels of 1, 1.25, 5, and 10 percent for 49 days (Forsberg et al., 1976, as cited in Sassaman, 1987). No significant differences were observed between treated and control groups of animals. Administration of Biotrol (25 x 10^9 spores per gram) at a 1 percent level in the diet of 25 female and 25 male rats for 2 years revealed no significant differences between control and treated groups of animals (Barnes, 1970, as cited in Sassaman, 1987).

Reproductive and Developmental Toxicity

The literature contains no data about the reproductive or teratogenic effects of *B.t.*

Carcinogenicity

The literature contains no data about the carcinogenic potential of *B.t.*

Mutagenicicity

Growing root stems of *Allium cepa, A. savivum*, and *Vicia faba* were exposed to delta-endotoxin protein. All test materials were negative in all systems (Panda et al., 1979, as cited in Sassaman, 1987).

Quality of the Toxicity Data

The quality of the toxicity data for the spruce budworm chemicals and *B.t.* is listed in Table R-1b. The quality of the toxicity data base for carbaryl is

adequate. Sufficient data exist from available studies to evaluate all toxicity endpoints. Based upon the carbaryl tox one-liner (EPA, 1988v), no mutagenicity studies for DNA damage have been validated. No other data gaps exist for carbaryl.

Data on diesel oil and kerosene are not available for most toxicity endpoints. The quality of the data base for these two petroleum distillates must be considered inadequate.

Data do not exist for a number of toxicity endpoints for *Bacillus thuringiensis*. The quality of the data base for *B.t.* must also be considered inadequate.

Risk Of General Systemic And Reproductive Effects

Margins of safety (MOS's) were computed for workers and the public for routine operations (typical and worst-case exposures), and for accidents, for carbaryl, diesel oil, kerosene, the combined petroleum distillates, and for *B.t.* Tables IV-III through IV-VII list the computed MOS'S for these materials. The margins of safety were computed by dividing the laboratory-determined NOEL's in Table IV-I by the doses listed in the risk assessment (Appendix F).

Risk To The Public In Routine Operations

Risk to the Public From Routine-Typical Exposures

Tables IV-III through IV-VII show that margins of safety for the public in routine-typical spraying are greater than 100 for systemic effects for the 3 chemicals, for the combined petroleum distillates, and for *B.t.* Margins of safety for reproductive effects for the 3 chemicals also are all greater than 100. These large margins of safety mean that members of the public could be repeatedly exposed to these levels and suffer no adverse effects.

These results indicate that no systemic or reproductive effects are likely to result from the use of carbaryl or *B.t.* in spruce budworm suppression operations.

Risk to the Public From Routine Worst-Case Exposures

The routine worst-case scenarios were intended to indicate the upper bounds for public exposure to insecticide applications in the Pacific Northwest. The low probability of occurrence of each assumed event must be emphasized. It is extremely unlikely that anyone would receive a dose as high as those estimated here.

Margins of Safety From Routine Worst-Case Exposures

Tables IV-III through IV-VII show that MOS's for reproductive effects are greater than 100 for all chemicals and *B.t.* for the routine worst-case exposures. Margins of safety for systemic effects projected under this routine worst-case scenario are greater than 100 for carbaryl and kerosene. MOS's for diesel oil and the combined petroleum distillates are greater than 100 except for dermal and inhalation exposure to drift. These results indicate there is some slight risk of effects from diesel oil/petroleum distillate drift exposure.

Margins of Safety for Special Case Analyses

Margins of safety for persons drinking contaminated water from runoff in The Dalles Watershed analysis are listed in Table 4-3b of the risk assessment Appendix F. None of the MOS's are lower than 100 for any of the feeder streams. MOS's are greater than 1,000 for the reservoir itself, so there is little risk from runoff when large areas of a watershed are sprayed, even when rain occurs immediately after spraying.

Margins of safety for persons eating crops irrigated with contaminated water are given in Table 4-3c of the risk assessment appendix. MOS's are all greater than 100, indicating very low risk from this potential route of exposure.

Risk to the Public in Accidents

Table IV-VIII summarizes the risk to the public from direct exposure to aerial spray, from eating food directly hit at the highest application rate, and from drinking water that has received a dump of 200 gallons of spray mix.

The extent of effects would depend upon an individual's duration of exposure and any precautionary measures that were taken. For example, if people gathered a bushel of berries from a spray area, did not wash them but froze them, and then ate them every day for a month, they might experience ill effects such as nausea and dizziness. However, if people bathed after being in the forest or washed food items before eating them, the doses would drop (and thus substantially increase the margins of safety).

Again, it must be noted that these are one-time, rather than repeat or chronic exposures and comparison of these doses with the acute LD_{50}'s shows no one is at risk of fatal effects.

Risk To Workers From Routine Operations

Risk to Workers From Routine-Typical Exposures

In the routine-typical exposures, all categories of workers applying carbaryl, kerosene, and *B.t.* have MOS's greater than 100. This indicates that even workers chronically exposed, should suffer no ill effects. The efficacy evaluation (E.E.) team members had an MOS less than 100 for diesel oil and for the combined petroleum distillates. This means that unprotected E.E. team members who routinely apply carbaryl may experience some toxic effects from the kerosene-diesel oil mixture.

Risk to Workers From Routine Worst-Case Exposures

As summarized in Table IV-IX, carbaryl, diesel oil, and the combined petroleum distillates have MOS's less than 100 for routine worst-case exposure. The probability of workers receiving repeated daily doses as high as predicted here is extremely low. Therefore, even if a worker felt ill for a day or so from an unusually high dose, permanent damage would be unlikely. Most of the time, workers will be receiving doses less than those predicted in the routine worst-case scenario. Sensitive individual workers would be at greater risk.

Effects of the Use of Protective Clothing

It must be emphasized that the routine worker exposures and resultant margins of safety are what could be expected in most spruce budworm suppression programs in the Pacific Northwest for workers not wearing protective clothing or equipment. All of the studies from which the routine-realistic exposures were calculated are based upon workers wearing no protective clothing. The use of protective clothing can substantially reduce worker doses, as shown in field studies of worker exposure, and thereby increase their margins of safety.

Protective clothing can reduce worker exposures by 27 to 99 percent, as shown in a number of relevant field studies (See the risk assessment). The calculated doses in the risk assessment were based upon the assumption that workers work with bare hands and wear ordinary work clothing, such as cotton pants and short-sleeve shirts. It is common practice, however, for insecticide applicators to wear clothing that affords more protection. Typical clothing often includes long-sleeve shirts or coveralls, gloves, and hats.

Research has shown that such protective clothing can substantially reduce worker exposure. During insecticide applications to orchards, mixers reduced their exposure by 35 percent and sprayers reduced their exposure by 49 percent by wearing coveralls (Davies et al., 1982).

Risk to Workers From Accidents

Dermal doses estimated in this analysis tend to exaggerate the amount that would actually be received because the dermal penetration rates used in the calculations assume no time factor is involved; that is, the chemicals penetrate the skin immediately. In reality, the penetration rates involve a significant time factor because they were derived from studies in laboratory animals over a period of 1 to several days. Thus, workers would have to ignore their own safety and <u>not</u> wash the chemical off to receive doses as high as predicted in these accidents.

Margins of safety for worker accidents are presented in Table IV-X. Workers who spill 500 milliliters (about half a quart) of insecticide concentrate or spray mix on their skin may experience acute toxic effects, in particular, high levels of acetylcholinesterase inhibition, if they do not wash the chemical off. In the case of a spill of 500 milliliters of concentrate, the doses approach the LD_{50}. The carbaryl dose is 63 percent of the LD50; the diesel oil dose, 10 percent; and the kerosene dose, 3 percent of the LD50. For carbaryl in particular, this represents a clear risk of severe toxic effects if the chemical is not washed off.

Workers are not likely to be affected by carbaryl or kerosene if they are directly sprayed, but they may be affected by diesel oil (MOS = 58) and the combined petroleum distillates in the mixture (MOS = 45).

Cancer Risk

A worst-case analysis for cancer was conducted for carbaryl, diesel oil, kerosene, and the petroleum mixture. There are no data on *B.t.* carcinogenicity, so no quantitative cancer risk assessment could be performed for this material. The cancer risks for the chemicals are presented in Table IV-XI. The risks were computed using the following formula:

Cancer risk = cancer potency x lifetime dose

The lifetime doses for each type of exposure were computed as described in the risk assessment. The cancer potencies used in the analysis are listed in

Table IV-I and their derivation is described in the previous hazard analysis discussion.

Cancer Risks to the Public

Results for carbaryl, diesel oil, kerosene, and petroleum distillates indicate that no member of the public is at a greater than 8.5 in 100 million risk of cancer from routine exposures. Accidental exposures resulting from a spill into a pond present a cancer risk of 3.2 in 1 million for carbaryl, and 8.8 in 10 billion or less for the other chemicals.

Cancer Risk to Workers

Cancer risks to workers for a 30-year work life at various tasks are presented in Table IV-XI. Workers are not at cancer risk greater than 1 in 1 million for any task or chemical. Cancer risks for worker accidents also do not exceed 1 in 1 million for any chemical.

Comparison of Cancer Risks With Other Common Risks

Table IV-XII presents cancer risks resulting from several familiar hazards and occupational risks. Motor vehicle accidents have a risk of fatality that averages 2 in 10,000 per person each year. Over a 30-year period, the cumulative risk would be 6 in 1,000. A variety of hazards that have an approximate risk of 1 in 1 million include smoking 2 cigarettes, eating 6 pounds of peanut butter, or drinking 40 sodas sweetened with saccharin. Many occupational risks are greater. Working for 30 years in agriculture or construction has a risk of about 1.8 in 100, and in mining and quarrying, the risk is even greater: 3 in 100 over 30 years.

Risk Of Effects From *B.t.* Contaminants (Bioburden)

John Ogle of Agriculture Canada (1988) reports a study in which three *B.t.* formulations were tested for contamination with other microorganisms. Dipel contained fecal streptococci at a level of 1 to 10 million per billion international units of *B.t.* The manufacturer, Abbott Laboratories, was alerted and implemented measures that reduced the contaminant to a level of less than one thousand per billion international units. The Canadians plan to reduce this to less than 100.

Studies in humans who were administered *B.t.* by various routes (oral, ingestion, inhalation) have indicated no adverse effects at the doses tested (Sassaman, 1987). No definitive proof has been found that current *B.t.* formulations would contribute to the overall bioburden of human disease-causing microorganisms, such as virus or streptococcus. The current situation can be evaluated as follows (USDA, 1988):

In over 18 years of *B.t.* use, there have been no scientifically documented cases or evidence of *B.t.*-caused illness directly attributable to forestry-use situations. This long history of use, and a special study on the health effects of *B.t.* spray programs conducted by the Oregon Department of Human Resource's Health Division between 1985-87, have not resulted in [the identification of] any cause and effect relationships between *B.t.* use and human illness. Thus, they appear to corroborate the apparent safety of this biological pesticide.

Low levels of extraneous microorganisms do exist in *B.t.*; however, these low levels do not affect the overall safety of *B.t.* The same environmental bacteria are also present at similar levels in water, food, milk, and other dairy products. The chances of exposure to low levels of extraneous microorganisms may be greater from eating or drinking ordinary food products than from *B.t.* use in forestry.

Another concern recently expressed was the possibility of enterotoxins being present in *B.t.* products. Manufacturers of *B.t.* products advise us that due to steps taken in the manufacturing process, it is unlikely that enterotoxins would be present in distributed products.

A final concern has been *B.t.* contamination of food or feed. Given current information, and under forestry use conditions, the probability of *B.t.* contaminating food or food products is highly unlikely. During all the years of *B.t.* use in agriculture and forestry, no evidence has been seen that *B.t.* grows on food, produces enterotoxins, significantly increases the bioburden, or causes unacceptable contamination.

Thus, it appears that humans exposed to *B.t.* in spruce budworm suppression operations may be at some low level of risk from eye or skin irritation or infection, but are not at risk of any systemic effects from *B.t.*

Risk Of Heritable Mutations

No human studies are available that associate the insecticides in this analysis with heritable mutations. Furthermore, no risk assessments that quantify the probability of mutations from the insecticides are available in the literature or from EPA. Laboratory

studies constitute the best available information on mutagenic potential. Results of the mutagenicity assays conducted on the three insecticides are summarized in Table 2-4 of Appendix F.

For some of the insecticides, no acceptable mutagenicity tests exist. For these insecticides, a worst-case assumption is made that these insecticides have the potential to cause mutations in humans. In these cases, the results of carcinogenicity tests or cancer risk assessments can be used to estimate the worst-case risk for mutagenicity. The rationale for this assumption is summarized by the USDA (1985) as follows:

Since mutagenicity and carcinogenicity both follow similar mechanistic steps (at least those that involve genetic toxicity), the calculated risk of cancer can be used as a worst-case approximation of somatic cell mutation risk. The basis for this assumption is that both mutagenicity, and at least primary carcinogens, react with DNA to form a mutation or DNA lesion affecting a particular gene or set of genes. The genetic lesions then require specific metabolic processes to occur, or the cells must divide to insert the lesion into the genetic code of the cell.

We believe the cancer risk provides a worst-case approximation to heritable mutations because:

1.All chemicals known to induce heritable germ cell mutation in mammals also produce cancer in mammals and almost always at a lower total dose.

2.Many chemicals that are carcinogens in rodents fail to induce heritable germ cell mutations even at the maximum tolerated dose (MTD).

3.Mammalian meiotic processes in gonadal tissue appear to be much more efficient in eliminating DNA lesions than somatic cells.

4.Human epidemiology studies of populations exposed to genotoxic carcinogens (radiation exposures in Nagasaki and Hiroshima) have demonstrated significant induction of cancer but no evidence of heritable mutations.

Carbaryl was nonmutagenic in the majority of assays conducted and were nononcogenic in all of the carcinogenicity tests performed; therefore, it can be assumed that its germ cell mutagenic risk is slight to negligible. Kerosene and diesel oil both contain PAH's and are considered to be possibly mutagenic.

Other Possible Effects Of The Insecticides

Synergistic Effects

Synergistic effects of chemicals are those that occur from exposure to two or more chemicals either simultaneously or within a relatively short period of time. For example, forestry workers exposed to the fungicide thiram have experienced skin blotching and nausea from drinking alcoholic beverages within 10 days of their thiram exposure. Synergism occurs when the combined effects of the two chemicals cannot be predicted based upon the known toxic effects of the individual chemicals, or when their combined effect is much greater than the sum of the effects of each agent alone. For example, a mixture of the herbicides 2,4-D and picloram has produced skin irritation in test animals while neither insecticide alone has been found to be a skin irritant. Cigarette smoke and asbestos are both known carcinogens. When inhaled in combination, they have been found to increase cancer risk eight fold above the risk of persons exposed to asbestos who do not smoke.

Risks From Insecticide Mixtures

Simultaneous exposure to more than one chemical is likely in cases where those chemicals are combined in a single spray mixture, such as the carbaryl-diesel oil mixture.

The EPA guidelines for assessing the risk from exposures to chemical mixtures (EPA, 1986a) recommend using additivity models when little information exists on the toxicity of the mixture and when components of the mixture appear to induce the same toxic effect by the same mode of action. They suggest in their discussion of interactions (synergistic or antagonistic effects) of chemical mixtures that "there seems to be a consensus that for public health concerns regarding causative (toxic) agents, the additive model is more appropriate than any multiplicative model." Since carbaryl's effect is chiefly cholinergic, and diesel and kerosene are systemic toxicants, their effects were not considered additive. The evaluation of petroleum distillates assumed an additive model for the effects of kerosene and diesel oil in the Sevin 4 Oil mix.

Effects on Sensitive Individuals

If the response of a population of test animals to varying doses of a chemical follows a normal distribution (bell-shaped curve), the hypersensitive individuals are those on the left-hand side of the curve that respond at much lower doses than the average. A

safety factor of 10 has traditionally been used by regulatory agencies (NAS, 1977) to account for this intraspecies (interindividual) variation. Not all sensitive individuals will be covered by an MOS of 100 because human susceptibility to toxic substances can vary two to three orders of magnitude (Calabrese, 1985). (These individuals could correspond to the very tail of the bell-shaped curve.)

Factors Affecting the Sensitivity of Individuals

Factors that may affect individual susceptibility to toxic substances include diet, age, heredity, preexisting diseases, and life style (Calabrese, 1978). These factors have been studied in detail for very few cases, and their significance in controlling the toxicity of the proposed insecticides is unknown. However, enough data have been collected on other chemicals to show that these factors can be important.

Genetic factors also are known in some cases to be important determinants of susceptibillity to toxic environmental agents (Calabrese, 1984). Susceptibility to irritants and allergic sensitivity vary widely among individuals and are known to be largely dependent upon genetic factors. Race has been shown to be a significant factor influencing sensitivity to irritants, and some investigations have indicated that women may be more sensitive than men (Calabrese, 1984).

Persons with other types of preexisting medical conditions also may be at increased risk of toxic effects. For example, sensitivity to chemical skin irritants can be expected to be greater for people with a variety of chronic skin ailments. Individuals who are immunosuppressed due to illness or from therapeutic treatment may be susceptible to microbial agents not known to be infectious to normal individuals. Patients with these conditions may be advised to avoid occupational exposure to irritating chemicals or *B.t.* (Shmunes, 1980, as cited in Calabrese, 1984).

Allergic Hypersensitivity

A particular form of sensitivity reaction to a foreign substance is allergic hypersensitivity. Except for contact dermatitis in delayed allergic reactions, these are responses to high molecular weight organic molecules or whole cells. None of the insecticides in the Forest Service spruce budworm suppression program is of high molecular weight, so the immediate allergic reactions and the delayed allergic reactions, except for contact dermatitis, can be ruled out as possible toxic effects. Contact dermatitis may be induced by lower molecular weight substances, such as the catechols of poison ivy, cosmetics, drugs, or antibiotics (Volk and Wheeler, 1983). Benzocaine, neomycin, formaldehyde, nickel, chromium, and thiram are all known to produce these reactions (Marzulli and Maibach, 1983).

A series of dermal sensitization studies showed no evidence that *B.t.* could induce allergic hypersensitivity (Fisher and Rosner, 1959 as cited in Sassaman, 1987).

Likelihood of Effects in Sensitive Individuals

Based upon the current state of knowledge, individual susceptibility to the toxic effects of the insecticides cannot be specifically predicted. As discussed above, safety factors have traditionally been used to account for variations in susceptibility among people. The margin-of-safety approach used in this risk assessment takes into account much of the variation in human response, as discussed earlier by Calabrese (1985). As described in the introduction to this risk assessment, a safety factor of 10 is used for interspecies variation; an additioanl safety factor of 10 is used for within-species variation.

Thus, the normal margin of safety of 100 for both types of variation is sufficient to ensure that most people will experience no toxic effects. However, unusually sensitive individuals may experience effects even when the margin of safety is equal to or greater than 100.

Some people may develop contact dermatitis from insecticide exposure. However, the small, infrequent exposures of the public should limit the possibility of their experiencing this type of reaction.

Effects from Inert Ingredients in Insecticide Formulations

Inert ingredients are chemicals that are added to the active ingredient to prepare a pesticide formulation. Inert ingredients provide a carrier for the active ingredient that facilitates the effective application of the pesticide, but that is not intended to supplement the pesticide's toxic properties. The single inert of concern in this analysis, kerosene, has been fully analyzed in the risk assessment.

Cumulative Effects

In a given year, up to approximately 1,350 square miles (850,000 acres) might be treated with insecticides for budworm suppression. The treated area would thus comprise less than 1 percent of the total land area of the two States. Moreover, the

treatments would occur, for the most part, in the remote areas of these densely forested lands. In general, treatment units are sprayed only once in a given year, then not treated again until a number of years later. The later treatment also may be with a different insecticide.

No individual member of the public is likely to receive repeated exposures to any of the insecticides because of the remoteness of most treatment units, the widely spaced timing of repeated treatments, and the use of a variety of insecticides for different purposes. In addition, the precautions taken by the Forest Service in their treatment operations make any dose at all to the public unlikely.

Summary Of Human Health Effects Of The Alternatives

Alternative A - No Action

This alternative should have no effect on human health because no chemical insecticides or biological controls are to be used.

Alternative B

This alternative presents the lowest risk of the alternatives apart from the No-action Alternative. *B.t.* appears to present little risk of acute or chronic health effects, although there is a general lack of data on reproductive, cancer, and other toxicity endpoints. Should data become available in these areas, the use of *B.t.* would be reassessed. Because Abbott Laboratories has reduced the presence of other microorganisms in its *B.t.* formulation, there appears to be little risk of any public health effects from bioburden in their product.

Alternative C

Carbaryl poses a human health risk only in the case of accidents. The petroleum distillates, kerosene and diesel oil, associated with carbaryl application do present a risk under routine worst case conditions and in accidents. Therefore, this alternative presents the highest risks to human health of the four alternatives. The petroleum distillates present a degree of uncertainty in the risk evaluation because of lack of data on their toxicity. Should additional data become available, their risks would be reassessed.

Alternative D

Human health risks of this alternative would be intermediate between Alternatives B and C. Risks would be reduced to the extent that *B.t.* is used instead of carbaryl.

Mitigating Measures

For any project that is implemented, a public information plan will be developed to ensure that timely notification is given about when and where spray operations will take place. Two general groups need notification, the general public and organizations that may have people working or recreating in the area. Members of the public will be given the opportunity to receive individual notice if they make a special request. Warning signs which are posted on the perimeter of treatment units will be bilingual (English and Spanish).

Irreversible Or Irretrievable Effects

Alternative A - No Action

No irreversible effects on resources have been identified. There is an irretrievable net loss of timber (wood fiber) production associated with this alternative. This net loss is estimated to be 1.5 billion board feet (BF) or an average of about 933 board feet per acre. The timber volume loss would be distributed over the next 70 years, assuming harvest schedules do not change substantially, and no further budworm control projects are implemented for the duration of the current outbreak. If a suppression project were to be initiated later, only a portion of the projected net loss would be irretrievably lost.

Alternatives B, C, and D

No irreversible effects on resources have been identified. Implementation of the action alternatives would avert most of the total net loss under the No-action Alternative. Recouping 100 percent of the estimated loss could be accomplished only with a highly successful treatment program.

Considering budworm effects on timber production as part of the baseline resource condition, budworm suppression projects represent investment opportunities. In other words, various portions of the estimated 1.5 billion BF volume at risk may be protected by investing various amounts of funds in a suppression program.

Energy Requirements And Conservation Potential

Alternative A - No Action

Energy requirements and conservation potential would be unchanged from those expected due to ongoing Forest management operations.

Alternatives B, C, and D

Implementation of these alternatives would involve consumption of fossil fuels by power aircraft and ground-based support vehicles. Other than minor savings possible through conservative use of vehicles, no major opportunities for energy conservation were identified.

Economic Efficiency And Local Impacts

Western spruce budworm infestations are a natural component of the biological environment of western coniferous forests, and their sporadic occurrence can, over time, alter the forest resource characteristics. This impact can influence the flow of future forest resource outputs. The flow may be reduced or enhanced at various points in time depending upon the severity of the infestation and the type and condition of the resource being affected.

Forest resources are managed to produce outputs that are beneficial to society. Protection of the resources and the flow of outputs is necessary. The level of protection provided from forest pests is a resource allocation decision. This decision must weigh the social benefits of minimizing undesirable resource impacts against the social costs of resources expended by protection measures and of any adverse economic, social, and environmental effects.

One purpose of the economic analysis is to value identified and quantified effects (both benefits and costs) resulting from an infestation, whether or not the outbreak is treated. Economic effects may be expressed in either dollar or nondollar values and can be classified into two categories: real and pecuniary (Musgrave and Musgrave, 1973). Both categories have a benefit and cost dimension.

Real effects refer to those impacts that have the potential to change the material well-being of society, such as the loss of standing mature timber or fish habitat. Of interest is the identification and social valuation of material resources expended (cost) and resources preserved or produced (benefits) by a pest management activity.

Direct control is considered economically efficient when benefits that can be valued exceed costs of suppression. The ratio of benefits to costs (benefit-cost ratio) is used to compare the relative cost efficiency of treating alternative analysis units. Units with benefit-cost ratios greater than 1.0 are considered cost-efficient investments. The larger the benefit-cost ratio exhibited by an analysis unit, the more attractive is the investment opportunity.

A pest-management alternative will also result in both short- and long-term local economic impacts. These are typically measured by changes in income, earnings, employment, output, and other economic and financial conditions.

Local economic impacts reflect both real and pecuniary effects. Pecuniary effects are benefits and costs that accrue locally, but occur at the offsetting expense or gain to other locations. By definition, they do not contribute to the material welfare of society as a whole, although they may be socially desirable. Rather, pecuniary effects reflect shifts of material well-being from one part of society to another, and between individuals and locations. Society's concern with an equitable distribution of benefits and costs, and the impacts of changing levels of economic activity on local and regional communities, often necessitates an examination of pecuniary effects. Changes in wage rates, income, earnings, employment, output, and price levels are frequently used to measure pecuniary effects and local economic impacts. Also, positive pecuniary effects or local impacts may result regardless of whether or not an alternative is economically efficient.

Methods

The methods used to quantify and value changes in forest resource output flows and other information pertinent to the economic analysis are elaborated in Appendix E. These methods are specifically tailored to valuing the resource effects identified in the Environmental Consequences section of the EIS. Each analysis unit in the site-specific EA will be assessed for relative economic efficiency by examining the relationship between their respective predicted benefits and costs. Economic efficiency criteria are presented to assist decisionmakers in selecting units for application of a pest management alternative (which includes the possibility of no action).

In some instances, insufficient information exists to quantify the immediate biological effects of the infestation or treatment measures, and there is no

methodology for projecting eventual resource output changes. There is no basis for evaluating the economics of these biological effects. The implications of these situations can only be considered in a qualitative manner.

Alternative A - No Action

Under the No-action Alternative, a long-term reduction in the future supply of fiber is projected for most analysis units. Some areas of the infestation may experience small areas of substantial mortality. To the extent this leads to timber salvage sales and subsequent processing of timber, local economic activity will increase over the short term.

The No-action Alternative entails no investment expenditures in direct control. No benefits result in terms of averted losses. The economic loss associated with inaction is the benefit to be ascribed, in part or whole, to an action alternative.

Alternatives B, C, and D

To the extent funding is available, investment in direct suppression with *B.t.* or carbaryl will be made in analysis units exhibiting the greatest net financial and intangible benefits. Total net benefit accruing to this alternative is a measure of economic efficiency which indicates an improvement in the Nation's material well-being.

Direct suppression will also lead to various economic impacts. In the short term, project expenditures in regional and local trade, services, and other economic sectors will bolster economic activity. Over the longer term, a pest management alternative will ensure the future availability of a greater supply of timber for the local processing industries. This result will set the stage for higher levels of future local economic activity which, in turn, will produce other beneficial regional and community impacts.

Social Factors

The effects of both alternatives on consumers, civil rights, minority groups, and women are estimated to be minor. Generally, these effects are related to the supply of wood fiber and the resulting cost of wood products. Primary and secondary employment associated with the manufacture of wood products is also a consideration.

Short-term Use Versus Long-term Productivity

"Short-term" uses are generally those that determine the present quality of life for the public. Short-term uses of Forests in the Pacific Northwest Region typically include timber harvest, recreation, livestock grazing, transportation, utility corridors, and wildlife habitat. Decisions about these short-term uses are usually made through each National Forest Land and Resource Management Plan.

Compared to all activities that take place in a Forest, a relatively narrow spectrum of management activities is considered in this EIS. Pest management helps provide the flow of goods and services associated with the short-term uses of a Forest. The process presented here for managing spruce budworm--and many of the mitigation measures--are designed to protect the long-term productivity of the land.

"Long-term productivity" refers to the capability of the land to support sound ecosystems producing resources such as forage, timber, wildlife, and water. Management activities associated with short-term uses (for example burning, use of machinery, or removal of woody debris) may reduce the natural productivity of some portions of the National Forests. How much the long-term productivity is reduced is not known because investigations of these effects have only recently begun.

The insecticides examined in the EIS have no known long-term effect on long-term productivity. However, it is known that any management activities have the potential to reduce the natural productivity of the land if certain operating guidelines are not followed. Each Forest Plan is developing management standards and guidelines designed specifically to protect long-term productivity. In addition, mitigation measures were developed for management activities considered in this EIS.

Alternative A may have an adverse effect due to a greater risk of extensive and severe wildfires. Alternative B may have a slight positive effect on long-term productivity as it will reduce mortality without a broad impact on beneficial, nontarget invertebrates.

Incomplete Or Unavailable Information

Incomplete or unavailable information was sometimes encountered in the process of preparing this EIS. The

implications of these situations and how they were handled are discussed here.

The purpose of the environmental analyses contained in this EIS is to "present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public" (40 CFR 1502.14)

Uncertain Data and Estimates

Data and information collected for the various analyses in this EIS, as well as the resulting estimates of effect and conclusions, vary in precision and accuracy. Some are based on censuses and many mutually-confirming studies. Others are based on samples and a few studies; some are estimates by professional specialists drawing on extensive experience with individual disciplines. The standard for determining the depth of analysis is that analysis be sufficient to provide "a clear basis for choice among options"--in this case, a choice among the four alternatives considered in this EIS.

Uncertainty in data and information is often the result of the inherent variability of natural phenomena. Uncertainty due to inherent variability can be expressed through a variety of means, including statistical measures of variation, estimates of ranges, and qualitative descriptions.

Sometimes, uncertainty is the result of incomplete or unavailable information. If the information that is incomplete or unavailable is essential to the decision to be made--in this case, selection of one of the four alternatives considered in this EIS--then a more rigorous standard for analysis and reporting is required (40 CFR 1502.22). The more rigorous standard specifies an orderly, careful, and open professional approach in dealing with uncertainty.

Reasonably Foreseeable Significant Adverse Effects

An open public process was used in preparing this EIS to identify significant issues. Issues identified are issues because of the potential for reasonably foreseeable significant adverse impacts on the human environment. The potential impacts are in the areas of human health, social and economic effects, and environmental effects. See Chapter I for a discussion of the issues and the scoping process.

Economic Impacts

Western spruce budworm management will affect the Forest Service's ability to provide goods and services. Predicted decline in forest growth as a result of budworm defoliation can be reasonably estimated. In the area of social and economic effects, there is sufficient information to provide a clear basis for making a choice among options with confidence.

Environmental Impacts

Environmental effects are reasonably well understood. The uncertainty associated with estimating environmental effects is due to the (often great) inherent variability and diversity associated with the natural environment. By using appropriate assumptions and professional judgment, effects of actions can be reasonably estimated with confidence. (These estimated effects are presented as the main part of this chapter.) While no estimate of effects for a given alternative is absolutely correct, the relative effects--compared to other alternatives--is correct. There is sufficient information with regard to environmental effects to provide a clear basis for choice among options.

Human Health Concerns

Human health concerns related to managing western spruce budworm by using insecticides is an issue.

A detailed and systematic determination of the quality of available information for human health effects of insecticies is identified in the section on Human Health Effects in this chapter. Information that is incomplete or unavailable for human health effects of insecticides is summarized in Appendix F.

The costs of obtaining more precise and conclusive data were estimated and were found to be exorbitant. While there is incomplete and unavailable information, much information about the human health effects of insecticides does exist. A large portion of the information that does exist was developed in support of registration of insecticides by the Environmental Protection Agency.

Information is incomplete or unavailable for human health effects of insecticides. Data gaps exist. Information is incomplete or unavailable in the following areas:

- Field studies on exposure to workers.
- Information on public exposure.
- Field data on residue levels in plants and animals.
- Mutagenicity study data for carbaryl (DNA damage)
- Toxicity information on the cumulative effects from exposure to forestry-use insecticides, other pesticides, and/or other chemicals.

- Toxicity, infectivity, and exposure information for *B.t.* to supplement the data from the history of its use.

Statement of Relevance

The relative human health effects of insecticides can be compared among alternatives. Comparisons are made in this EIS for accidents from spills in a variety of environmental settings. (See the Human Health Effects section of this chapter, and the comparison section of Chapter II.) The uncertainty for which there is incomplete and unavailable information is for the actual human health risks from insecticides.

Summary of Information

Information that is currently available is summarized in several places in this EIS:

Appendix F - Qualitative Health Risk Data

Appendix F - Hazard Analysis

Appendix F - Details of Mutagenicity and Carcinogenicity

Chapter IV - Human Health Effects

Evaluation of Impacts

The human health effects of the alternatives are compared in Chapter II. The detailed human health effects of the alternatives are discussed in Chapter IV.

Many research studies were used to determine what effects are currently known. A great number of research studies have been conducted on the use of insecticies, many in support of registration by the Environmental Protection Agency. Enough information is available that risk can be reasonably characterized for both insecticides being considered. Quantitative estimates of risk are contained in Appendix X, which is a detailed quantitative human health risk assessment.

Unavoidable Adverse Effects

Implementation of any alternative would result in some adverse environmental effects that cannot be avoided. Standards and guidelines and mitigating measures developed in this EIS are intended to keep the extent and duration of these effects within acceptable levels, but adverse effects cannot be completely eliminated.

Because this EIS examines alternative methods for managing western spruce budworm outbreaks the focus is on how the different methods could affect the environment. From this perspective, there are three areas of potentially significant adverse effects:

- human health risks;
- environmental effects on fish, wildlife, domestic stock and nontarget insects.
- economic effects.

The potential for adverse effect varies with each alternative, and is discussed in detail in this EIS.

Figure IV-I

Components of the Risk Assessment Process

Hazard Analysis	Exposure Analysis
Identify what kinds of health effects have been observed in laboratory studies, including animal models, and at what levels of exposure	Identify types of people exposed
Identify any health effects that have been observed in humans	Identify expected routes of exposure
Determine median lethal dose (LD_{50}) for acute effects from laboratory rat study	Estimate the exposure each person would receive by each route, using both routine and extreme case scenarios
Determine lowest no-observed-effect levels (NOEL's), if possible, for general chronic toxic effects, reproductive effects, and birth defects	Estimate frequency and duration of exposure
Determine whether the pesticide has carcinogenic or mutagenic potential	Calculate doses
Identify data gaps in toxicity information	

Risk Analysis

Compare doses to NOEL's and LD_{50}'s and discuss probability of acute and chronic effects (including birth defects) for routine through worst-case scenarios

Conduct extreme case analysis for cancer risk

Table IV-I

Toxicity Reference Levels Used in the Analysis of Human Health Risks

Chemical	Rat Oral LD (mg/kg)	Systemic NOEL (mg/kg/day)	Reproduction/ Developmental NOEL (mg/kg/day)	Canger Potency per (mg/kg/day)
Carbaryl	270	10.0	20.0	0.076
Diesel Oil	7,380	7.38	751	0.0000049
Kerosene	28,000	28	751	0.0000049
Petrol. Distil.	7,380	7.38	751	0.0000049
Bacillus thuringiensis				
Inhalation	—	1.4	—	—
Oral	—	500	—	—

Table IV-II

Quality of the Toxicity Data Base

Compound	Acute Toxicity	Systemic	Toxicity Endpoint Reproductive Effects	Cancer	Mutagenicity
Carbaryl	A	A	A	A	M
Diesel Oil	A	M	M	I	M-I
Kerosene	A	M	I	I	I
B.t.	A	M	I	I	M-1

A - Adequate—adequate information available. More studies unlikely to change assessment.

M - Marginal—but usable information available for evaluating toxicity. Additional studies may significantly change assessment.

I - Inadequate—inadequate information available for evaluating toxicity.

Table IV-III

Carbaryl Margins of Safety

	Systemic		Reproductive	
	Typical Exposures	Worst-case Exposures	Typical Exposures	Worst-case Exposures
Public				
Dermal				
Veg. Contact	10,000	10,000	10,000	10,000
Dermal & Inhalation				
Drift	6,700	1,000	10,000	2,000
Dietary				
Water	10,000	10,000	10,000	10,000
Fish	10,000	10,000	10,000	10,000
Meat	10,000	1,000	10,000	10,000
Peas or Beans	5,000	2,000	9,832	2,000
Berries	10,000	5,000	10,000	300
Cumulative				
Fisherman	10,000	5,000	10,000	9,000
Hunter	7,000	1,000	10,000	3,000
Workers				
Pilot	10,000	10,000	10,000	10,000
Mixer/loader	10,000	2,000	10,000	4,000
Observer	7,000	1,000	10,000	2,000
Card Checker	5,000	1,000	10,000	3,000
E.E. Team	10,000	3,000	10,000	6,000
Backpack	2,000	200	5,000	500
Accidents				
Spill onto Worker		-17[1/]		-8.5
Broken Hose		-24		-2.1
Direct Spray - Adult		120		1,316
Direct Spray - Child		79		878
Peas or Beans		100		1,158
Spill into Water				
200 Gallons into Pond		9.4		19

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 10.0 and a reproductive NOEL of 20.0.

[1/] When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added

MOS rounded to nearest significant digit.

Table IV-IV

Diesel Oil Margins of Safety

	Systemic		Reproductive	
	Typical Exposures	Worst-case Exposures	Typical Exposures	Worst-case Exposures
Public				
Dermal				
Veg. Contact	8,000	4,000	10,000	10,000
Dermal & Inhalation				
Drift	600	100	10,000	10,000
Dietary				
Water	8,700	1,500	10,000	10,000
Fish	2,700	500	10,000	10,000
Meat	10,000	2,000	10,000	10,000
Peas or Beans	1,000	200	10,000	10,000
Berries	2,200	400	10,000	10,000
Cumulative				
Fisherman	1,600	300	10,000	10,000
Hunter	1,300	300	10,000	10,000
Workers				
Pilot	2,000	550	10,000	10,000
Mixer/loader	1,000	180	10,000	10,000
Observer	600	100	10,000	10,000
Card Checker	450	110	10,000	10,000
E.E. Team	100	30	8,000	3,000
Backpack	200	20	10,000	2,000
Accidents				
Spill onto Worker		-99[1/]		1.0
Broken Hose		-49		2.1
Direct Spray - Adult		58		5,931
Direct Spray - Child		39		3,954
Peas or Beans		130		10,000
Spill into Water				
200 Gallons into Pond		2.1		209

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 7.38 and a reproductive NOEL of 751.

1/ When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

MOS rounded to nearest significant digit

Table IV-V

Kerosene Margins of Safety

	Systemic		Reproductive	
	Typical Exposures	Worst-case Exposures	Typical Exposures	Worst-case Exposures
Public				
Dermal				
Veg. Contact	10,000	10,000	10,000	10,000
Dermal & Inhalation				
Drift	8,000	1,500	10,000	10,000
Dietary				
Water	10,000	10,000	10,000	10,000
Fish	10,000	6,000	10,000	10,000
Meat	10,000	10,000	10,000	10,000
Peas or Beans	10,000	3,000	10,000	10,000
Berries	10,000	6,000	10,000	10,000
Cumulative				
Fisherman	10,000	4,000	10,000	10,000
Hunter	10,000	4,000	10,000	10,000
Workers				
Pilot	10,000	7,000	10,000	10,000
Mixer/loader	10,000	2,500	10,000	10,000
Observer	8,100	1,300	10,000	10,000
Card Checker	6,100	1,500	10,000	10,000
E.E. Team	1,000	400	10,000	10,000
Backpack	2,700	300	10,000	7,500
Accidents				
Spill onto Worker		-26 1/		1.0
Broken Hose		-3.7		7.2
Direct Spray - Adult		770		10,000
Direct Spray - Child		510		10,000
Peas or Beans		1,700		10,000
Spill into Water				
200 Gallons into Pond		27		728

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 28 and a reproductive NOEL of 751.

1/ When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

MOS rounded to nearest significant digit

Table IV-VI

Petroleum Distillate: Diesel Oil + Kerosene Margins of Safety

	Systemic		Reproductive	
	Typical Exposures	Worst-case Exposures	Typical Exposures	Worst-case Exposures
Public				
Dermal				
Veg. Contact	6,000	3,000	10,000	10,000
Dermal & Inhalation				
Drift	500	100	10,000	8,000
Dietary				
Water	7,000	1,100	10,000	10,000
Fish	2,000	300	10,000	10,000
Meat	10,000	18,000	10,000	10,000
Peas or Beans	900	200	10,000	10,000
Berries	2,000	300	10,000	10,000
Cumulative				
Fisherman	1,000	200	10,000	10,000
Hunter	1,000	200	10,000	10,000
Workers				
Pilot	1,700	400	10,000	10,000
Mixer/loader	700	150	10,000	10,000
Observer	500	80	10,000	7,500
Card Checker	400	90	10,000	9,000
E.E. Team	60	25	5,980	2,000
Backpack	200	20	10,000	2,000
Accidents				
Spill onto Worker		-99 1/		1.0
Broken Hose		-64		1.6
Direct Spray - Adult		45		4,604
Direct Spray - Child		30		3,069
Peas or Beans		100		10,000
Spill into Water				
200 Gallons into Pond		1.6		163

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 7.38 and a reproductive NOEL of 751.

1/ When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

MOS rounded to nearest significant digit.

Table IV-VII

Bacillus thuringiensis Margins of Safety (Systemic Effects Only)

	Typical	Worst-case
Public		
Inhalation[1/] (Drift)	5,000	2,000
Dietary[2/]		
Water	303,000	75,000
Peas or Beans	40,000	11,000
Berries	80,000	22,000
Cumulative		
Hunter	60,000	17,000
Workers		
Pilot[1/]	12,000	6,000
Mixer/loader[1/]	8,000	4,000
Observer[1/]	5,000	2,000
Accidents		
Direct Spray of Garden Vegetables	NA	6,711
Spill into Pond	NA	108

1/ Based on 1.4 mg/kg/day for human volunteer inhalation.

2/ Based on 500 mg/kg/day for rats feeding on 1 percent Biotrol in their diets.

NA = Not applicable.

MOS rounded to nearest significant digit

Table IV-VIII

Margins of Safety for the Public in Accidents (Systemic Effects Only)

	Adult Sprayed	Child Sprayed	Eat From Sprayed Garden	Drink Water From Pond Spill
Carbaryl	700	440	550	9.0
Diesel Oil	60	40	130	2.0
Kerosene	800	500	1,500	27.0
Petrol. Distil.	50	30	100	2.0
B. thuringiensis	NA	NA	7,000	100

NA = Not applicable.

MOS rounded to nearest significant digit

Table IV-IX

Summary of Spruce Budworm Insecticide Margins of Safety for Workers in Routine Worst-case Exposures

Chemical	MOS's for Systemic Effects	MOS's for Reproductive Effects
Carbaryl	All greater than 100	All greater than 100
Diesel Oil	MOS's less than 100 for observer (98), E.E. team (28), and backpack sprayer (21).	All greater than 100
Kerosene	All greater than 100	All greater than 100
Petrol. Distil.	MOS less than 100 for observer (76), E.E. team (22), card checker (88), backpack (16)	All greater than 100
B. thuringiensis.	All greater than 100	All greater than 100

Table IV-X

Worker Margins of Safety From Accidents

	Spill on Worker		Broken Hose		Accidental Spray	
Chemical	**Systemic**	**Repro**	**Systemic**	**Repro**	**Systemic**	**Repro**
Carbaryl	-95[1/]	-86	-1	-1	120.0	132.0
Diesel Oil	-99	1	-3	41	58.0	5,931.0
Kerosene	-26	1	5	143.0	770.0	10,000.0
Petrol. Distil.	-99	1	64	1	45.0	4,604.0
B. thuringiensis	NA	NA	NA	NA	NA	NA

NA = Not applicable.

1/ When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

Table IV-XI

Relationship to Background Cancer Levels (Chances Per Lifetime)

	Carbaryl	Diesel	Kerosene	Petroleum Distillates
Public				
Dermal & Inhalation				
Drift	No Risk	Much Less	Much Less	Much Less
Dietary				
Water	1.2E-08	Much Less	Much Less	Much Less
Fish	2.9E-09	Much Less	Much Less	Much Less
Meat	5.3E-09	Much Less	Much Less	Much Less
Peas or Beans	8.5E-08	Much Less	Much Less	Much Less
Berries	4.3E-08	Much Less	Much Less	Much Less
Cumulative				
Fisherman	1.5E-08	Much Less	Much Less	Much Less
Hunter	6.0E-08	Much Less	Much Less	Much Less
Workers				
Pilot	No Risk	Much Less	Much Less	Much Less
Mixer/loader	No Risk	Much Less	Much Less	Much Less
Observer	No Risk	Less	Much Less	Less
Card Checker	No Risk	Less	Much Less	Less
E.E. Team	No Risk	Less	Less	Less
Backpack	No Risk	Much Less	Much Less	Less
Accidents				
Spill onto Worker	No Risk	Less	Less	Less
Broken Hose	No Risk	Less	Much Less	Less
Direct Spray—Adult	No Risk	Much Less	Much Less	Much Less
Direct Spray—Child	No Risk	Much Less	Much Less	Much Less
Direct Spray —				
Garden Vegetables	5.1E-08	Much Less	Much Less	Much Less
Spill into Pond				
—200 Gallons	Slightly above	Much Less	Much Less	Much Less

No Risk—Risks are upper 95 percent confidence limits.

Slightly Above—Calculated cancer risk, 1 in 100,000 and 1 in 1,000,000

Less—Calculated cancer risk less than 1 in 1,000,000

Much Less—Calculated cancer risk less than 1 in 1,000,000,000

Table IV-XII

Lifetime Risk of Death or Cancer Resulting From Everyday Activities

Activity	Need to Accumulate a One-in-one Million Risk of Death[1/]	Average Annual Risk Per Capita[2/]
General Risks		
Motor vehicle accident	1.5 days	2×10^{-4}
Falls	6 days	2×10^{-5}
Drowning	10 days	4×10^{-5}
Electrocution	2 months	5×10^{-6}
Lightning	2 years	5×10^{-7}
Occupational Risks		
Mining and quarrying	9 hours	1×10^{-3}
Agriculture	15 hours	6×10^{-4}
Manufacturing	4.5 days	8×10^{-5}
Trade	7 days	5×10^{-5}
Firefighting	11 days	8×10^{-4}

1/ Based on living in the United States

2/ Numbers shown exponentially in this table are to be interpreted as follows:

1×10^{-3} means 1 in a thousand.
1×10^{-4} means 1 in ten thousand.
1×10^{-5} means 1 in one hundred thousand.
1×10^{-6} means 1 in a million.
1×10^{-7} means 1 in ten million.

Table IV-XIII

Carbaryl Wildlife Risk

Representative Species	Realistic Dose (mg/kg)	Extreme Dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference Species
Flicker	1.1	11.0	156	780	Grouse
Dove	0.9	8.8	156	780	Grouse
Jay	1.2	11.0	156	780	Grouse
Kingfisher	0.5	4.7	156	780	Grouse
Screech owl	1.5	15.0	156	780	Grouse
Mouse	3.3	32.0	55	275	Mouse
Rabbit	0.4	5.7	142	710	Rabbit
Deer	0.1	1.1	40	200	Mule deer
Fox	0.3	2.6	30	150	Cat
Toad	1.5	14.6	156	780	Grouse
Snake	1.9	18.2	156	780	Grouse
Cow	0.0	1.4	40	200	Mule
Chicken	0.2	1.5	156	780	Grouse
Dog	0.1	0.5	30	150	Cat

Table IV-XIV

Diesel Oil Wildlife Risk

Representative Species	Realistic Dose (mg/kg)	Extreme Dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference Species
Flicker	4	40.4	3,280	16,400	Mallard
Dove	3.3	32.8	3,280	16,400	Mallard
Jay	4.2	41.7	3,280	16,400	Mallard
Kingfisher	1.9	18.9	3,280	16,400	Mallard
Screech owl	5.5	54.8	3,280	16,400	Mallard
Mouse	11.3	113	1,476	7,380	Rat
Rabbit	1.6	21.3	1,476	7,380	Rat
Deer	0.2	4.3	1,476	7,380	Rat
Fox	1	10.3	1,476	7,380	Rat
Toad	11.8	118	3,280	16,400	Mallard
Snake	15	150	3,280	16,400	Mallard
Cow	0.15	4.9	1,476	7,380	Rat
Chicken	0.63	6.7	3,280	16,400	Mallard
Dog	0.3	2.9	1,476	7,380	Rat

Table 1V-XV

Representative Wildlife and Domestic Species

Representative Niche	Representative Species
Insectivorous birds	Flicker
Granivorous birds	Dove
Omnivorous birds	Jay
Piscivorous birds	Kingfisher
Carnivorous birds	Owl
Small omnivorous mammals	Mouse
Medium herbivorous mammals	Rabbit
Large herbivorous mammals	Deer
Carnivorous mammals	Fox
Insectivorous amphibians	Toad
Carnivorous reptiles	Snake
Domestic animals	Cattle
	Chicken
	Dog

Table IV-XVI

Representative Aquatic Species Used in the Analysis

Common Name	Scientific Name
Rainbow trout	Salmo gairdnerii
Brook trout	Salveliuus fontinalis
Cutthroat trout	Salmo clarki
Largemouth bass	Micropterus salmoides
Smallmouth bass	Micropterus dolomieui
Bluegill	Lepomis macrochirus
Yellow perch	Perca flavescens
Water flea	Daphia sp.
Stonefly	Plecoptera sp.
Scud	Gammarus sp.

Table IV-XVIII

Acute Toxicity Risk Analysis for Petroleum Distillates

Representative Species	Risk Level[1/,2/]
Typical concentration, (EEC) = 0.038 ppm	
Rainbow trout	Slight
Brook trout	Slight
Cutthroat trout	Slight
Largemouth bass	Slight
Smallmouth bass	Slight
Bluegill	Slight
Yellow perch	Slight
Water flea	Slight
Stonefly	No data
Scud	No data
Worst-case concentration, (EEC) = 0.24E pmm	
Rainbow trout	Significant
Brook trout	Significant
Cutthroat trout	Significant
Largemouth bass	Significant
Smallmouth bass	Significant
Bluegill	Significant
Yellow perch	Significant
Water flea	Significant
Stonefly	No data
Scud	No data

1/ Source: EPA, 1986

2/ Based on LC_{50} or EC_{50} (ppm) and Q-value (EEC/LC_{50}).

Table IV-XVIII

Acute Toxicity Risk Analysis for Carbaryl

Representative Species	Risk Level[1/,2/]
Typical concentration, (EEC) = 0.0091 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	No risk
Stonefly	No risk
Scud	No risk
Worst-case concentration, (EEC) = 0.056 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	No risk
Stonefly	No risk
Scud	No risk

1/ Source: EPA, 1986

2/ Based on calculated LC_{50} or EC_{50} (ppm) and Q-value (EEC/LC_{50}).

Table IV-XIX

Carbaryl Risk From Accidents

Representative Species	Risk Level[1/],[2/]
200 gallon spill into pond, EEC = 38 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	Significant
Stonefly	Significant
Scud	Significant
Direct spraying of water body at maximum rate, EEC = 0.094 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	No risk
Stonefly	No risk
Scud	No risk

1/ Source: EPA, 1986

2/ Based on calculated LC_{50} or EC_{50} (ppm) and Q-value (EEC/LC_{50}).

Appendix

Moth (adult)

APPENDIX A

List of Preparers

(in alphabetical order)

Don Bilyeu

Education:

A.A., Psychology, Clackamas Community College, 1973

B.A., Psychology, Portland State University, 1978

Experience:

USDA Forest Service (13 years)

Teacher/Counselor, Timberlake Job Corps, Mt. Hood N.F., 3 years

Visitor Information Specialist, Gifford Pinchot N.F., 2 years

Public Affairs Specialist, RO R-6, 8 years

Doug Burns

Education:

B.S., Forest Management, Northern Arizona University, 1976

Silvicultlure Institute, Oregon State University, 1986

Experience:

USDA Forest Service (11 years)

Renewable Resource Evaluations, Intermountain Forest Range Experimental Station, 2 years

Planning, Rogue River N.F., 5 years

Silviculture, Willamette N.F., 4 years

Paul Hessburg

Education:

B.S., University of Minnesota

Ph.D., Forest Pathology, Oregon State University, 1984.

Experience:

USDA Forest Service (4 years)

Naomi Kennedy

Experience:

USDA Forest Service (8 years)

Gifford Pinchot N.F., 5 years

Tongass N.F., 2 years

Pacific Northwest Region, 1 year

Dean Longrie

Education:

B.S., Botany, University of Wisconsin, 1968

M.S., Wildlife Ecology, Michigan State University, 1970

Ph.D., Wildlife Ecology, Michigan State University, 1972

Experience:

USDA Forest Service (10 years)

Forest Wildlife Biologist, Mt. Hood N.F., 10 years

Bureau of Land Management, Oregon Office, 2 years

Assistant Professor Wildlife, University of Wisconsin, Stevens Pt., 2 years

Federal Power Commission, Washington, D.C., 1 year

Consultant, Beaver, Pennsylvania, 3 years

Charlotte Martin

Education:

Chase Business College, 1975

Experience:

USDA Forest Service (10 years)

National Park Service, Fort Vancouver National Historic Site, 2 years

Gifford Pinchot N.F., Writer/Editor, 1 year

Gifford Pinchot N.F., Writer/Editor technical reports, forest plans, 2 years

Michael H. O'Day

Education:

B.S., Forest Management, University of Michigan, 1971

Experience:

USDA Forest Service (7 years)

Resource specialist, data systems manager.

Resource inventory and mapping systems specialist, Pacific Northwest Region.

Other EIS assignments: Mount St. Helens National Volcanic Monument EIS; spotted owl EIS project. Concurrent assignment: data systems manager for the nursery and spruce budworm EIS teams.

Forest products industry, 7 years.

Roger Ogden

Education:

B.S., Forestry, Oklahoma State University, 1972

Silviculture Institute, Utah State University, 1976

Experience:

USDA Forest Service (16 years)

Silviculture, Winema N.F., 2 years

Silviculture, Mt. Hood N.F., 2 years

Silviculture, Salmon N.F., 1 year

Timber, Winema N.F., 5 years

Silviculture, Mt. Hood N.F., 3 years

EIS Project Leader, Mt. Hood N.F., 2 year

EIS Project Leader, PNW Region, 1 year

Sandra Perrin

Experience:

USDA Forest Service (10 years)

Pacific Northwest Region

Roger Sandquist

Education:

B.A., Biology, 1967

M.S., Entomology, 1969

Ph.D., Entomology, 1971

U.S. Environmental Protection Agency, Pesticide Registration, 1 year

Experience:

USDA Forest Service (14 years)

WO Pesticide Specialist, 3 years

Multiregional Pesticide Specialist (westside), 3 years

R-6 Entomologist, 8 years

Mike Schafer

Education:

B.S., Forestry, University of Minnesota, 1968

Certified Silviculturist

Experience:

USDA Forest Service (17 years)

Forest Pest Management, Pacific Northwest Region, 2 years

Klamath N.F. Pacific Southwest Region, 6 years

Grand Mesa-Uncompahgre-Gunnison N.F., Rocky Mountain Region, 3 years

San Juan N.F., 2 years

Rio Grande N.F., 4 years

Leslie Sekavec

Education:

B.S., Forest Management, Oregon State University, 1980

Experience:

USDA Forest Service (10 years)

Planning, Deschutes N.F., 1 year

Silviculture, Deschutes N.F., 4 years

Timber, Mt. Baker-Snoqualmie N.F., 3 years

Silviculture, Mt. Baker-Snoqualmie N.F., 2 years

Dennis Weber

Education:

B.S., Forest Management, University of Wisconsin, 1972

Experience:

USDA Forest Service (13 years)

Planning Forester, Mt. Hood N.F., (7 years)

Assistant Planner, Willamette N.F., (2 years)

Forester, Willamette N.F., (2 years)

Forestry Technician, Siskiyou N.F., (2 years)

Marc R. Wiitala

Education:

B.S., Economics & Political Science, Northern State College, 1970

M.S., Economics, South Dakota State University, 1972

Ph.D., Economics & Agricultural Economics, University of Nebraska, 1979

Experience:

USDA Forest Service (7 years)

Pacific Northwest Region, S&PF, 7 years

State of Montana Department of Community Affairs, 1 year

USDA Economic Research Service, 2 years

APPENDIX B

Consultation

Public Involvement Process

There has been public involvement throughout development of this EIS.

The public's interest in the management of the western spruce budworm situation in Oregon and Washington continues at a high level. The Interdisciplinary (ID) Team which conducted this EIS used the public involvement process developed in 1986, 1987, and expanded on in 1988, as the basis for this EIS.

In 1986, an extensive public involvement process was initiated which included gathering background information from documents of other agencies pertaining to budworm management, newspaper clippings, and appeals from past decisions; as well as issues and concerns gathered over the previous years. In addition, mailings were conducted, several news releases were made, and a number of public meetings were held.

In October 1987, a letter was sent to cooperators and all interested individuals on the mailing list, requesting additional input and indentification of any new issues and concerns. Based on these responses, it was determined that the major issues and concerns described in the 1986 and 1987 Environmental Analyses were still valid.

Several meetings were held with interested or concerned parties in both Oregon and Washington in 1985, 1986, and 1987 for additional input. Throughout the fall of 1987, several news releases were made regarding the analysis of the western spruce budworm situation.

Informal consultation with the United States Department of the Interior, Fish and Wildlife Service, has been initiated through telephone contact and written request regarding the status and mitigation measures for threatened and endangered species occurring within the current outbreak area. The U.S. Fish and Wildlife Service provided lists of threatened or endangered species. Mitigating measures for no effect on threatened or endangered species were developed for their concurrence.

In May 1988, to help identify issues, concerns, and opportunities, a mailing requesting comments and concerns on the current western spruce budworm infestation was distributed to approximately 2,000 addresses. Press releases were mailed to the media in the affected areas requesting comments and concerns on the proposed Environmental Impact Statement on management of the western spruce budworm in Oregon and Washington.

A total of 206 responses were received through distribution of the scoping brochure and included approximately 550 substantive comments. These comments, along with comments, concerns, and opportunities from prior public input were analyzed to identify issues, alternatives, and analysis criteria needed to evaluate the possible alternatives.

Major Issues And Concerns

Beginning in 1981, and continuing through successive years of environmental assessments (EAs), numerous concerns have been expressed about the current western spruce budworm outbreak, and associated spray programs, in the Pacific Northwest. The issues and concerns developed during the 1984 northeastern Oregon analysis were used as a starting point to build upon during 1985. The public involvement steps used for scoping in 1986 included meetings and written inquiries. In 1986, 1987, and 1988, some additional public meetings were held by individual Forests. In addition, interested parties were solicited in writing for additional issues and concerns that were not addressed in prior EAs. Public meetings, personal consultations, news clippings, and correspondence resulted in identification of public issues and management concerns. These items reflected the views of concerned individuals, forest-based industries, landowners of various-sized forest holdings, forest resources user groups, conservation and environmental groups, Indian tribes, and representatives of local, State, and Federal agencies and governments.

Use of Public Input in the Process

The publics response to the above steps contained a broad array of opinions about issues, concerns, opportunities, and alternative actions. Using this information, the ID Team identified the eight major issues elaborated in Chapter 1 and developed the alternatives and mitigation measures described in Chapter 2 of this EIS.

Based on responses to mailings conducted as part of this EIS, and concerns identified in past EAs, eight major public issues were identified in the scoping process. They include silviculture; water quality and quantity; fish, wildlife, and domestic animals; economics; human health; effectiveness of treatment methods; timeliness of treatments; and fuels and fire.

Individuals and Organizations Consulted

During the course of the present and past years' analyses, the following individuals and organizations were consulted:

Robert Cooper, Research Technician, Wenatchee NF

Norm Anderson, Forestry Technician, Wenatchee NF

Jim Taylor, Resourse Assistant, Wenatchee NF

Susan J.L. Stepniewski, District Wildlife Biologist, Wenatchee NF

Bill Garrigues, District Hydrologist, Wenatchee NF

Steven Kessler, Forest Fisheries Biologist, Wenatchee NF

Terry Luther, Wildlife Biologist, BIA

Richard French, Forester, BIA

Rodney Johnson, Wildlife Biologist, Umatilla NF

Randy Dohrmann, Resource Asst., Umatilla NF

Rod Miller, Forest Wildlife Biologist, Wallowa-Whitman NF

Dean Longrie, Forest Wildlife Biologist, Mt. Hood NF

Richard Gritz, Forest Fish Biologist, Malheur NF

Kirk Wolff, Forest Hydrologist, Malheur NF

Paul Joseph, I & D Forester, OR. Dept. Forestry

Mark Henjum, Regional Nongame Biologist, OR. Dept. F&WL

Ed Schroeder, Silviculturist, Boise Cascade Corp.

Rick Brathovde, Silviculturist, Boise Cascade Corp.

Bud Fisk, Area Forester, Boise Cascade Corp.

Dan Blatt, Wildlife Area Manager, WA. Dept. Fisheries

Phil Peterson, Habitat Manager, WA. Dept of Game

Chuck Chambers, Lead Biometrician, WDNR

Deborah Naslund, Data Mgr. Nat. Heritage, WDNR

Larry Charlton, Ellensburg Local Manager, WDNR

Bernard Murphy, Klickitat Dist. Manager, WDNR

Dianna Hwang, Wildlife Biologist, U.S. Fish & Wildlife

Russell Peterson, Field Supervisor, U.S. Fish & Wildlife

Jim Michaels, Wildlife Biologist, U.S. Fish & Wildlife

Grant Gunderson, Wildlife Biologist, USDA FS, RO

Kathy Johnson, Wildlife Biologist, USDA FS, RO

Gary Larsen, Group Leader VMT, USDA FS, RO

Iral Ragenovich, Group Leader Entomology, USDA FS, RO

James Hadfield, Group Leader Pathology, USDA FS, RO

Roger Sandquist, Entomologist, USDA FS, RO

Eric LaGasa, Entomologist, WA. Dept. Ag.

Ronald S. Yockim, Prairie Wood Products, Riddle, Oregon

Jean C. Meddaugh, Oregon Environmental Counsel, Portland, Oregon

Lou Levy, Cunningham Sheep Co., Pendleton, Oregon

Larry L. Cribbs, Our National Forests, Inc., LaGrande, Oregon

James C. Geisinger, Northwest Forestry Assoc., Portland, Oregon

Paulette L. Pyle, Oregonians for Food & Shelter, Salem, Oregon

Terry L. Witt, Oregonians for Food & Shelter, Salem, Oregon

William R. Keyser, City of The Dalles, The Dalles, Oregon

John E. Dennee, City of The Dalles, The Dalles, Oregon

Sandra Saint-John, Private Individual, Portland, Oregon

John J. Howard, Union County Court, LaGrande, Oregon

Chet & Mary Schiewe, Private Landowners, Pendleton, Oregon

Wayne Wehling, Washington State University, Pullman, Washington

Stanley D. Butzer, Bureau of Land Management, Portland, Oregon

Anthony R. Morrell, Bonneville Power Admin., Portland, Oregon

Russell D. Peterson, USDI Fish & Wildlife Service, Portland, Oregon

Ronald W. Hesselman, USDI Fish & Wildlife Service, Clackamas, Oregon

Art Stearns, WA. Dept. of Nat. Resources, Olympia, Washington

Richard French, USDI Bureau of Indian Affairs, Portland, Oregon

Tom Haberstroh, USDA Bureau of Indian Affairs, Pendleton, Oregon

Glen Lisle, USDI Bureau of Indian Affairs, Toppenish, WA.

LeRoy Kline, Oregon State Dept. Forestry, Salem, Oregon

Dave Overhulser, Oregon State Dept. Forestry, Salem, Oregon

Paul Buffam, Retired Forest Service, Beaverton, Oregon

Carl H. Stoltenberg, College of Forestry, OSU, Corvallis, Oregon

Evelyn Lee, Willamette Inst. Biol. Contr., Eugene, Oregon

Duncan C. Wurm, WA. Friends of Farms/Forests, Olympia, WA.

Ralp Saperstein, WFIA, Portland, Oregon

William G. Howard, Chief Forester Boise Cascade, Yakima, WA.

Karen Murphy, W. WA. Toxics Coalition, Seattle, WA.

Dave Smith, Team Leader, Gypsy Moth EIS, Region 8

Joe Pessich, Portland, Oregon

Larry Gross, Washington Office, Washington DC

[illegible]

NDI Bureau [illegible]

[illegible]

[illegible] Pine St. [illegible]

[illegible]

APPENDIX C

Standards And Guidelines

Project Implementation Plan

A written project plan will be developed for the implementation of spray operations. In addition to routine considerations, the project plan will specifically address safety, public notification, monitoring, and accidents and spills.

Public Information Plan

For any project that is implemented, the Incident Commander (IC) will prepare and follow a public information plan to ensure that timely notification is given about when and where spray operations will take place. Two general groups need notification, the general public and organizations that may have people working or recreating in the area. Members of the public will be given the opportunity to receive individual notice if they make a special request. In particular, range permittees have requested notification. The public will be notified about any possible adverse effects that spray may have on automobile finishes. Warning signs that are posted on the perimeter of treatment units will be bilingual (English and Spanish).

Pretreatment Reviews

Budworm population levels must be verified through early spring larval sampling before commencement of insecticide application. Weather situations may change and be responsible for the collapse of populations.

Before treatment, the IC will review the current status of analysis units that fall within Wildernesses, roadless, or further study areas to ensure that any treatment decisions that may have been made on these areas remain valid.

Prespray Operations

Block boundaries, heliports, and airstrips will be mapped. Spray blocks will be designed using the following topographic and other features as block boundaries whenever possible:

- Draws and streams
- Ridges
- Roads
- Property lines
- Slope and aspect
- Altitude
- Other distinguishing landforms
- Sensitive areas

Heliports and airstrips will be located so they are close to or within the blocks to be sprayed. They must be large enough to accommodate all the necessary spray equipment and personnel. All USDA Forest Service aircraft safety limits must be met or exceeded. They must also be accessible to ground transportation, and meet all environmental standards.

Spray Operations And Contract Administration

Experience during recent years has shown that certain items concerning the structure and administration of spray contract operations must be emphasized in order to ensure safe and satisfactory work. These items are highlighted in the following paragraphs:

Insecticide formulations will be applied under weather conditions that comply with the manufacturer's recommendations. These standards vary somewhat, depending upon the particular formulation being used. Such factors as air movement, wind speed, air temperature, relative humidity, probability of rain, presence of moisture on foliage, air turbulence, temperature inversion, and visibility will be considered when making decisions to spray or not to spray. Tolerance guidelines for each of these

environmental parameters are included in the insecticide application contract.

In order to minimize the range of spray droplet size, the use of rotary atomizer nozzles will be required.

Contractors' equipment will be required to meet all applicable operational and safety regulations. Inspections will be conducted before and during operations. Tank trucks are particular items of interest.

Pilot cars will be used to guide the contractors' insecticide transportation vehicles to the helispots.

The IC will ensure all contract administration personnel are fully qualified to perform their functions, and are fully aware of their responsibilities and authorities.

Application Team Leaders and other contract administration personnel will exercise shut-down authority when they observe aircraft safety violations.

The IC will place special emphasis upon minimizing the following types of errors:

- Spraying areas that have been designated for spray avoidance.
- Treating designated areas more than once.
- Spraying areas outside the designated spray blocks.
- Nonuniform coverage of the target area.

Aerial Observation

In order to control and monitor insecticide application, each application aircraft, or team of aircraft, will be accompanied by an observation aircraft staffed with a fully qualified aerial observer. Observation aircraft are an integral part of ensuring areas are treated with insecticides in an effective manner. Aerial observers monitor swathing, spray behavior, calibration, and keep an accurate record of which areas have been treated and when. They also serve as a safety backup to the spray pilot to help locate aerial hazards, avoid sensitive areas, and provide immediate location of a spray aircraft if it crashes. In past projects, when observation aircraft were not used one-on-one with spray aircraft, the quality of application decreased to unacceptable levels (NOTE: application contractors are paid on gallons of insecticide sprayed, not on acres treated in an acceptable manner; thus, without close supervision, there is a tendency to be more concerned with the number of gallons sprayed rather than the quality of application). With less than one observation aircraft per spray aircraft, time is wasted ferrying between spray blocks, calibration checks are not as reliable, the contractors' word must be taken for which areas have been treated, and there is less control of protection of sensitive areas.

Each observer will be familiar with the local terrain and have authority to control all activities of the application aircraft. Observers and application pilots will fly each spray block for familiarization prior to spraying.

Spray Deposit Cards

Spray deposit cards are used as a quality check to see if insecticide coverage is adequate, and if the insecticide is reaching the target in an acceptable form. This information, when gathered just after an area has been sprayed, is extremely valuable to the Application Team Leader. This information, along with that of the Aerial Observer, is used to determine if spraying should continue. The information from the spray cards is also valuable in helping the Aerial Observer determine results on-the-ground in relation to conditions observed in the air. A few spray cards placed around each budworm post-treatment evaluation plot will give a qualitative check on coverage obtained. This often gives some insight into post-treatment results.

At least one card line will be placed in each spray block. A few cards will be placed at each budworm evaluation plot. Ground Observers will place cards at their location within the spray block to give immediate feedback on spray deposit after the aircraft has made its run.

Spray Standards

Weather

Moisture, wind, humidity, and air and ground temperatures are important factors affecting spray drift and upward rise of spray droplets.

The maximum allowable wind speed while spraying is 8 miles per hour. No spraying will be attempted, and all spraying will cease, if wind speeds are in excess of 8 mph in the spray block. If the application aircraft pilot is unable to compensate for spray drift caused by wind speeds less than 8 mph, or if wind will cause drift into off-target areas, spraying will stop.

No spraying will occur when fog or low clouds cover the spray area.

Spraying may occur when foliage is damp or wet as long as the foliage is not dripping. This condition will usually exist in the early morning hours.

No spraying will take place when it is raining, or if rain is predicted within 6 hours of spray application. Spraying can occur following rain if the foliage is not dripping.

Conditions may exist that will cause a rapid decrease in humidity in a very short time. When this occurs, and it is detected that spray droplets are not reaching the ground, spraying will cease until the humidity stabilizes.

Spraying will not occur when the air temperature at application altitude is 35 degrees or less, or above 70 degrees Fahrenheit. Application altitude is defined as the altitude of the application aircraft.

If the temperature at application altitude is warmer than the surface temperature (even if less than 70 degrees), the spray will begin to "hang". From the side, the spray pattern would have a "camel back" appearance. Spraying will stop when this condition exists.

If the surface temperature rises faster than the application altitude temperature, an up-draft will occur causing the spray to rise. This can be especially evident on southern exposures and dark terrain features early in the morning. When this condition exists, spraying will cease in the area. This may be a localized phenomenon and spraying could continue in another portion of the block.

An inversion occurs when cool air is trapped at the surface by a layer of warmer air. An inversion is not a problem if the application aircraft can work within the layer of cooler air. If the aircraft cannot work in the lower area, the spray will not penetrate the cooler air mass and will drift off target. Spraying will be suspended when this condition exists. Surface and application altitude temperatures should be monitored to determine when the inversion breaks down and application can resume.

Mechanical Operations

Application operations will be suspended if any of the following problems with aircraft are present:

- Aircraft mechanical problems
- Malfunctioning spray system including; plugged nozzles, leaking system, nonoperating quick dump (unless load is calculated for nonjet-tisonable load)
- Communications problems
- Pilot is not in a functional condition

If there is one batch truck present, spraying activities will be suspended if any of these conditions exist:

- No operator available
- Nonfunctioning meters
- Leaky or faulty system
- Nonoperating pump

Personnel

Spraying will be suspended if the following personnel are not present or are nonfunctional:

- Observation pilot
- Application pilot
- Aerial observer
- Application Equipment Manager (unless duties are performed by Application Team Leader)
- Contractor's ground crew
- Fuel truck driver

Sensitive Areas and Situations

Avoid flying over organic farms. If farm is in approach or departure path from spray block, ensure that area is not inadvertently treated. Suspend spraying when weather conditions exist that could cause drift into adjacent blocks.

Avoid unecessary flights over areas indentified as containing horses, turkeys, and other exotic or timid animals.

Avoid flying over areas containing large numbers of people outside, such as sporting events, golf courses, schools, etc.

If protesters are in the area, suspend spraying where there is any threat to employees, contractors' employees, or public safety. Spraying will continue only if there is no safety threat present.

Any areas set aside at the Forest Supervisor's discretion will be avoided, or buffered during spray operations.

The Pacific Northwest Forest and Range Experiment Station must be contacted to determine if long-term research projects are located in proposed treatment areas. These projects are to be avoided and buffered if requested.

Accident Contingency Plan

The Project Director will prepare and follow a written contingency plan for dealing with accidents and insecticide spills. The plan will specify other agencies

involved, and list authorities and responsibilities. The plan will detail the notification procedures. Provisions for minimizing potential adverse effects from spilled insecticides will be specified.

Spill Management

The objective of spill management is to eliminate the possibility of spills by planning and monitoring any operations where insecticides, diesel, jet fuel, or other petroleum-based products are being used. In the event of a spill, project personnel will take immediate action to correct the problem. These protective efforts will be continuous and progressive; actions taken will be dependent upon the product and the nature of the spill.

Contractors' Responsibilities

Cleanup and disposal of any leaks or spills will be the responsibility of the contractor. Cleanup and disposal will be accomplished in accordance with any applicable State laws and regulations. Forest Service and State personnel will assist the contractor in any containment notification or monitoring effort, but will not assume any of the contractor's liabilities.

Prior to beginning work, the contractor will submit to the COR a spill plan which indicates to the Forest Service, the State Department of Environmental Quality (DEQ), and other agencies that the contractor is aware of the environmental concerns and is implementing as many safety procedures as is deemed necessary. The spill plan should indicate the contractor has the knowledge and ability to minimize the effects of any accidents that might occur.

The spill plan must be a document that stands on its own. It will be approved, before operations begin, by the State DEQ responsible for the area in which the contractor will be spraying.

Project Personnel Responsibilities

Contractor spill plans will be reviewed by the Incident Commander, Operations Section Chief, Contract Administrator, and the Safety Officer. Designated project personnel will provide guidance and assistance to the contractor to meet project objectives.

The Contract Administrator will ensure that the contractors involved in incident spills, complete control and cleanup actions to the extent necessary to protect the environment and meet standards set by the appropriate Federal and State laws and regulations. Documentation and followup will be done by the Safety Officer.

Incident Procedures

All incident spills will be reported in accordance with the Operation Plan and Project Management Guidelines. The nature of the incident spill will determine how it is handled.

Small leaks or spills will be handled by on-scene personnel. Such leaks or spills will be corrected by the contractor and recorded in the Contract Administrator's log. Such incidents may not hinder the operation progress. This type of incident may include the following: a leaking valve, an equipment malfunction, overfilling a tank, or any problem that can be corrected by simple maintenance.

A minor incident does not cause any significant interruption of the project operation. Minor incidents are those that do not threaten life, health, or property directly and immediately. Minor incidents are not perceived by the public to be a problem. Minor incidents, such as leakage of petroleum products at a heliport or soil contamination from a leaking tank truck, will be corrected through prompt action by project personnel. Minor incidents will be recorded in the Contract Administrator's log, and may require some outside notification.

If a major incident occurs, disruption to the project operation is imminent. Major incidents are emergencies or incidents that cause an immediate threat to life, property, or resources. An overturned tank truck that has dumped insecticide into a stream supplying nearby domestic water is an example of a major incident. Major incidents will require notification of various jurisdictions, and requests for assistance will be as needed.

Spill Control Techniques

The following control techniques may work in many incidents, but the contractor and incident personnel must be prepared to react to a spill using the most up-to-date procedures available:

Dirt berms may be used to stop the spread of a spill or divert it to less sensitive areas. Petroleum products float on water, providing an opportunity to contain the spill by means of floating barriers such as straw or specifically designed absorbent materials.

Spills can be soaked up with dirt, sawdust, newspaper, or almost anything that will absorb the contaminant. Special absorbent pads or pillows may be necessary. Sweeping compound works well to soak up spills on paved or hard surfaces.

State DEQ or other specialists may suggest methods of control to neutralize a contaminant and prevent damage.

If an incident occurs, thorough investigation and analysis of the cause must be completed to assist in development of future preventative measures. Investigations may include personnel from an outside agency if an incident involves multi-jurisdictions.

Economic Considerations

The initial economic ranking and selection of areas for treatment is predicated, in part, upon a projection of per-acre treatment cost. This projection is usually based on bid- and project-cost data from previous years. Changes between past and current market conditions, as well as the size of the suppression effort, can cause differences between projected treatment costs and actual contract bid award costs. Any significant differences between actual and projected costs will necessitate a reevaluation of the economic propriety of treatments.

When significant disparity arises between projected and actual bid-per-acre application costs, the economic information upon which initial treatment decisions were made becomes invalid. This undermines the quality of management decisions to treat various areas. Under such circumstances, it will be necessary to reevaluate the economic priorities of areas, using actual bid prices. Some units may no longer meet the initial economic criteria for selection. Under these circumstances additional consideration may be needed to review unit treatment priority.

Noneconomic And Incommensurable Considerations

Noneconomic considerations and forest outputs that are not amenable to dollar valuation often play a major role in the selection of treatment areas. When the treatment budget is limited, units which yield higher cost-benefit on dollar-valued outputs may be dropped in favor of those displaying significant noneconomic and nondollar values. The result is a loss in dollar benefits, often termed "opportunity cost" or "foregone benefits." When the costs of treatment are similar, a rational decision to drop a unit yielding greater dollar returns implies a judgment on the magnitude of the noneconomic and nondollar gain of the substitution. The implication is that the value of the newly included unit's noneconomic and nondollar benefits exceeds the reduction in dollar-valued benefits of the unit replaced. An example would be the treatment of a visual corridor to the exclusion of a highly productive timber area.

Decisionmakers must be fully apprised of the opportunity costs associated with selecting units for treatment primarily on the basis of noneconomic and nondollar values. Apprisal necessitates the decision process make a clear statement of the foregone dollar benefits or the opportunity cost. In this way, decisionmakers can better judge whether intangible and incommensurable values have a value to society in excess of the known and quantified benefits foregone.

Protection Of Water-related Resources

Aerial insecticide application near streams and open water is controlled by State law. In Oregon, State regulatory agencies have agreed that B.t. may be aerially applied parallel to and up to the edges of streams and open water. A variance must be obtained from the State Department of Ecology to apply B.t up to the edges of streams in Washington State.

A buffer zone must be left adjacent to streams, lakes, wetlands, and other waterways when applying carbaryl. This buffer strip must be at least one swath wide.

The following measures will be used to minimize the probability of unintentional adverse effects on water-related resources and nontarget organisms from spills or application errors:

Aircraft spray equipment calibration testing over wetlands or floodplains will be prohibited.

Transportation of insecticides or fuel on roads within municipal watersheds will be guided by pilot vehicles.

Helispots will not be located in or adjacent to meadowland or floodplains.

Wetlands, including lakes and ponds, which are large enough to identify from the air will not be oversprayed with insecticides. There may be relatively small wet areas that, because of the tree canopy cover, cannot be identified from the air which will be unavoidably but inadvertently sprayed.

Protection Of Nontarget Organisms

The IC of any spraying operation will coordinate with local State and Federal land managers to ensure that

appropriate protection measures are implemented to mitigate possible adverse effects to beneficial insects and the nesting habitat of eagles and other raptors. Mitigating measures for threatened or endangered species, developed with the concurrence of the U.S. Fish and Wildlife Service, will be incorporated into the project operations plan to ensure that treatment and related activities will have no effect.

In areas planned for treatment, the IC will coordinate with the Forest Service Area Ecologist to determine what action is appropriate to assure that threatened or endangered plants are protected. Areas important to threatened or endangered species will be avoided if necessary.

Protection Of Cultural Resources

Possible cultural resource sites in previously unsurveyed and undisturbed areas are a concern. The Project Director of treatment projects will ensure that areas such as planned helispots, truck parks, or staging areas are surveyed for cultural resource values by a qualified person before ground-disturbing activities occur. Any cultural resource sites discovered will receive appropriate protection.

Protection Of Wilderness Values

The Forest Service Manual defines several objectives in regard to management of insects and plant disease in Wildernesses (FSM 2324.1):

1. "To allow indigenous insect and plant diseases to play, as nearly as possible, their natural ecological role within wilderness.

2. To protect the scientific value of observing the effect of insects and diseases on ecosystems and identifying genetically resistant plant species.

3. To control insect and plant disease epidemics that threaten adjacent lands or resources."

The following policy will be followed when considering treatment in Wildernesses:

The life cycle of the western spruce budworm suggests that the lack of treatment of Wildernesses does not pose a threat to non-Wildernesses (i.e., adjacent) lands, nor threaten the resources within Wildernesses. Therefore, in the majority of instances, allow natural processes to continue without control in Wildernesses.

In situations where the spruce budworm infestation in a Wilderness might affect adjacent non-Wilderness resources, evaluate treatment on a case-by-case basis.

Continue to monitor the population levels "in a manner that preserves the wilderness character of the area."

If control measures become necessary in specific cases to prevent unacceptable damage to lands adjacent to a Wilderness, treatment measures must have the least impact on the Wilderness resource and be compatible with Wilderness management objectives.

Identification Of Visual Treatment Needs

Selection of an area to receive suppression of budworm activity for protection of visual values will be based on a priority system. Selection of areas proposed for treatment will be based on a priority system using criteria of sensitivity level, distance zones, and foliage quality objectives. The Landscape Architect on each National Forest will identify the priorities for suppression based on these criteria.

Distance Zones

Distance zones are divisions of a particular landscape being viewed. They are used to describe the part of a characteristic landscape that is being considered for budworm suppression. The three distance zones are:

Foreground

The limit of this zone is based upon distances at which details can be perceived. Normally in foreground views, the individual boughs of trees form texture. It will usually be limited to areas within one-fourth to one-half mile of the observer, but must be determined on a case-by-case basis as should any distance zoning.

Middleground

This zone extends from the foreground zone to 3 to 5 miles from the observer. Texture normally is characterized by masses of trees in stands of uniform tree cover. Individual tree forms are usually only discernible in very open or sparse stands.

Background

This zone extends from middleground to infinity. Texture in stands of uniform tree cover is generally

very weak or nonexistent. In very open or sparse timber stands, texture is seen as groups or patterns of trees.

Sensitivity Levels

Sensitivity Levels are a measure of people's concern for the scenic quality of the National Forests.

Sensitivity levels are determined for land areas viewed by those who: are traveling through the Forest on developed roads and trails; are using areas such as campgrounds and visitor centers; or are recreating at lakes, streams, and other water bodies.

Three sensitivity levels are employed, each identifying a different level of user concern for the visual environment:

- Level 1 - Highest Sensitivity
- Level 2 - Average Sensitivity
- Level 3 - Lowest Sensitivity

Sensitivity Level 1 includes all seen areas from primary travel routes, use areas, and water bodies where, as a minimum, at least one-fourth of the Forest visitors have a major concern for the scenic qualities. Examples are all areas seen from:

- Primary roads, primary trails used by hikers and horsemen, and primary use sites within National Parks, National Recreation Areas, Wildernesses, and other dedicated Wild Areas.
- All public transportation systems of national importance including railways.
- Primary areas of fishing, swimming, boating, and other active or passive recreation on or adjacent to water bodies such as streams, lakes, ocean, etc.
- Primary recreation areas (vista points, campgrounds, picnic grounds, beaches, visitor centers, trail camps, etc.)
- Primary resorts and winter sports areas.
- Primary geological areas.
- Primary botanical areas.
- Primary historical sites.
- Areas of primary importance for observation of wildlife.
- Primary summer home tracts.
- Highly sensitive communities where a large portion of the population is not directly related to performing Forest land management activities.

Sensitivity Level 1 also includes all seen areas from secondary travel routes, use areas, and water bodies where at least three-fourths of the Forest visitors have a major concern for the scenic qualities. Examples are areas seen from:

- Secondary roads and trails and use areas within, as well as to and from, National Parks, National Recreation Areas, Wildernesses and other dedicated Wild Areas.
- Secondary recreation sites that fit the definition above.

Examples of either primary or secondary routes which should always be assigned Sentivity Level 1 are:

- All roads classified as "scenic highways."
- All roads and trails leading directly to major areas of interest; National Parks, Wildernesses, major recreation composites, historic sites and areas, botanical sites, etc.

Sensitivity Level 2 includes all seen areas from primary travel routes, use areas, and water bodies where fewer than one-fourth of the Forest visitors have a major concern for scenic qualities. Examples are all areas seen from:

- All Federal, State, and primary County or Forest systems not listed under Level 1.
- Known low-flying air routes (includes noncommercial leisure flying).
- Communities where a large portion of the population is directly related to performing Forest land management activities.
- Other primary uses not included under Level 1.

Level 2 also includes all seen areas from secondary travel routes, use areas, and water bodies where at least one-fourth and not more than three-fourths of the Forest visitors have a major concern for scenic qualities. Examples are all areas seen from:

- Secondary County and Forest systems that fit the above definition.
- Secondary trail systems.
- All roads leading directly to secondary areas of interest and recreation composites.
- Secondary recreation areas (vista points, campgrounds, picnic grounds, etc.)
- Secondary uses of fishing, swimming, boating, and other active or passive recreation on or adjacent to water bodies such as streams, lakes, etc.
- Secondary geological areas.
- Secondary botanical areas.
- Secondary resorts.
- Secondary summer home tracts.
- Secondary historic sites.
- Areas of secondary importance for observation of wildlife.
- Does not include travel routes and use areas of only occasional visitation.

- Includes both existing and proposed (within 10 years).

Level 3 includes all seen areas from secondary travel routes, use areas, and water bodies where less than one-fourth of the Forest visitors have a major concern for scenic qualities. (Level 3 does not include any areas seen from primary routes or areas.) Examples are areas seen from:

- All County and Forest road systems, not in Levels 1 or 2, which are either permanent or temporary.
- Secondary Forest trail systems used primarily for fire protection and other administrative uses.
- Recreation sites of little or no consequence (such as an occasional unimproved hunter camp).
- Streams with little or no fishing use.
- Secondary roads or use areas with only occasional use.
- All National Forest land not seen from any travel route, use area, or water body.

Foliage Quality Objectives

Lands proposed for suppression will be assigned a foliage quality objective. The three quality foliage quality objectives are:

- RF - Retention of Foliage
- PRF - Partial Retention of Foliage
- MF - Modification of Foliage

These objectives are keyed to the values set forth in the sensitivity levels and distance zones. Each describes a different degree of acceptable change in color and texture from the natural landscape based upon the importance of esthetics.

Retention of Foliage

This visual quality objective provides for management of budworm defoliation at a level which is not readily evident. Color and texture changes will not be readily evident.

Partial Retention of Foliage

Budworm defoliation remains visually subordinate to the characteristic landscape. Defoliation may introduce color and texture changes, but changes should remain subordinate to the visual strength of the characteristic landscape.

Modification of Foliage

Under the modification of foliage quality objective, defoliation may visually dominate the original characteristic color and texture of the landscape.

Protection Of Threatened, Endangered, And Sensitive Plants

A potential impact on threatened and endangered sensitive plants is a loss or reduction in insect pollinators. Information on insects responsible for pollinating these plants was not found, therefore, the potential impact of *B.t.* and/or carbaryl on these insects was not analyzed. Carbaryl, because of its effect on a broader range of insect species, has the most potential for posing an impact.

Protocols established in the Forest Service Manual (FSM 2670) for biological evaluations and consultation shall be part of all project level assessments. Documentation of adherence to these protocols will be provided in the project level assessment, and will minimize the potential for adverse consequences in all alternatives considered.

Protection Of Threatened, Endangered, And Sensitive Wildlife

All Forest Service actions that could affect threatened, endangered, or sensitive species, or their habitat, will be preceded by a documented biological evaluation (FSM 2670). The biological evaluation process should determine species/habitat presence in the project area and, if present, potential adverse effects. A review of existing recovery plans, if appropriate, would be part of the biological process. Mitigation measures or project modification would be planned as appropriate to ensure the proposed activity would not adversely affect the recovery of any threatened, endangered, or sensitive species.

Protection Of Range And Forage

Prior to any treatment, coordination with local (County) weed control boards and appropriate State

(Oregon State Department of Agriculture) agencies will be made. This coordination will ensure that State and local efforts to control noxious weeds using biological agents will not be adversely affected by spruce budworm control agents.

Monitoring

Spray Projects will have a written monitoring plan. The following purposes of monitoring will be considered in the plan and implemented:

- To measure the accomplishment of the project insect population reduction objectives. (Post application)
- To measure insecticide residue in domestic water supplies within applicable analysis units. (Post application)
- Operations monitoring to provide timely feedback to the IC about the conduct of the operation.
- Spray deposit monitoring.
- B.t. sampling for clinically significant pathogens.
- Long-term monitoring of timber growth and yield of some selected forest stands. (Post treatment)
- Monitoring of effectivess of foliage retention in visually sensitive zones.

Personnel for each project area will be responsible for conducting water quality monitoring. A detailed plan will be developed for each project conducted.

In the event of an insecticide spill into a stream or body of water, water samples, drift net samples, and visual observations will be used to monitor insecticide distribution and environmental effects.

APPENDIX D

Western Spruce Budworm Management

Western spruce budworm management consists of two main strategies; prevention and suppression.

Prevention

The time to recognize the threat of western spruce budworm is before outbreaks occur. Prevention strategies are designed to reduce forest susceptibility to attack and damage by western spruce budworm outbreaks over the long term by use of silvicultural treatments. Long-term management strategies to reduce forest susceptibility to western spruce budworm attack and damage should be considered and addressed in the Forest planning process (FSM 1922).

Suppression

Suppression objectives are aimed at providing short-term protection to forest stands during an outbreak. Two basic suppression tactics are used: population reduction and foliage protection. Both of these tactics use chemical and/or nonchemical insecticides.

The population reduction tactic is aimed at reducing western spruce budworm populations to as low a level as possible, thereby reducing defoliation and damage. Once populations are reduced, natural regulating factors may maintain populations at low levels for several years.

Under the foliage protection strategy, an insecticide is applied to areas where defoliation has occurred for many years, and one or more years of additional budworm feeding will cause unacceptable damage. The objective of the foliage protection strategy is to prevent substantial defoliation in the year of treatment, saving enough foliage to reduce damage such as visual effects and tree mortality.

Suppression Project Analysis Procedures

Suppression activities to reduce western spruce budworm damage during an outbreak should be considered on a case-by-case basis. The NEPA process (FSH 1909.15) should be followed when analyzing the possible need for suppression. The following should be included in the analysis:

Description of Outbreak

Describe the nature and extent of the current outbreak. Forecast the expected course and duration of the outbreak.

General Physiographic Description

Describe the general physiographic characteristics of the affected areas. Describe the terrain features and forest cover present in the areas. Discuss sensitive resources and features, if any. Include a map of the affected area.

Ownership Description

Identify all landownerships (Federal, State, private) involved in the affected area. Describe landowner objectives and responsibilities.

Description of Resources At Risk

Describe the resources that have already been affected and those that will be affected in the future by the western spruce budworm outbreak. Resources such as timber, recreation, water, and visual quality may be affected. There may be conflicting resource objectives between or within the ownerships involved; nevertheless, all appropriate objectives should be considered.

Formulation of Suppression Alternatives

Budworm suppression alternatives should reflect issues identified in the scoping process (FSH 1909.15). Always analyze the following alternatives: no action, control using chemical insecticides, control using microbial insecticides, and vegetation manipulation. Some of these alternatives need substantial, detailed analysis, while others may not need to be considered in detail. For example, the vegetation manipulation alternative will usually be

eliminated from detailed analysis because it is a long-term management strategy which is not directly comparable to suppression alternatives; long-term budworm management strategies should be considered as part of the Forest planning process (FSM 1922). Discuss the reasons for eliminating any analyzed alternative from detailed consideration. Devote substantial treatment to each alternative considered in detail.

Description of Analysis Units

For analysis purposes, the affected area should usually be broken up into smaller units. Describe the units for which suppression alternatives are being analyzed. Explain the characteristics upon which the analysis units are based. Display these units on a map.

Evaluation of Physical and Biological Effects of Suppression Alternatives

Estimate the changes in physical and biological effects between the no-action and suppression alternatives. Consider effects on: regeneration and seed production; timber; recreation; fish and wildlife; and other aspects of the affected environment identified in the scoping process (FSH 1909.15). Estimate these effects relative to management objectives expressed in affected landowners' forest plans. For example, timber and wood fiber effects should be determined under the existing selection and schedule of timber management activities established by the Forest Plan, or by other Federal, State, or private landowner plans or stated objectives.

Evaluation of Economic Effects of Suppression Alternatives

Once physical and biological effects are determined, they must be expressed in economic terms. The purpose of the economic evaluation is to assess the costs and benefits associated with proposed suppression alternatives. Include both efficiency and local economic impacts in the analysis.

Local Economic Impacts

For each suppression alternative, describe changes in local income and employment, if any. The extent to which local economic impacts are addressed should be governed by the issues and concerns identified in the scoping process. A qualitative discussion of local economic impacts is often sufficient. When quantitative analysis is deemed necessary, methods such as input-output analysis and economic-base analysis can be used to estimate economic impacts.

Economic Efficiency

The economic efficiency evaluation assesses benefits and costs that can be expressed in monetary terms. Include only those effects identified as important during the scoping process. Describe changes in the value of outputs between the no-action and suppression alternatives. Changes in output values may be positive or negative.

Calculating Timber Economic Effects

A budworm outbreak on timber-producing lands usually disrupts management plans by affecting the timing and/or magnitude of timber yields and associated management activities. The purpose of the timber economic evaluation is to determine how an outbreak will affect the economics of timber production over time. While circumstances will vary according to geographic area, timber species affected, management practices, and other factors, the timber impact evaluation will usually include the following:

a) Description of timber harvest plans for each analysis unit under consideration. This would include the schedule of thinnings and final harvests prescribed in current management plans and objectives.

b) Projection of volume yield changes at each future harvest between no action and suppression alternatives. Whenever possible, use spruce budworm damage model projections.

c) Determination of timber value changes between the no-action and suppression alternatives based upon projected timber resource prices.

d) Estimates of any future timber management and reforestation costs expected to vary between the no-action and suppression alternatives.

Calculating Nontimber Economic Effects

The scoping process will identify resource outputs and effects which must be measured to adequately address issues and concerns. It is not necessary to include each of these outputs explicitly in the economic analysis. The issues and concerns should help determine the outputs for which an economic evaluation is desirable. Consider the following:

a) When substantial uncertainty surrounds estimation procedures for nontimber economic effects, it may be more informative to discuss these effects qualitatively.

b) If economic evaluations for nontimber resources are performed, these analyses should be displayed separately from the economic evaluation of timber effects. Include a brief discussion of the reliability of the data used in the analysis.

c) When quantifying nontimber benefits, use values specified in the most recent Forest Plan (for National Forest System lands), or the most recent Resources Program and Assessment if local or regional values do not exist. Values from recent Regional or local studies may be substituted for Forest planning values if there is sufficient reason, fully documented, to do so.

Calculating Suppression Project Costs

Total suppression project costs must include all costs necessary to accomplish the objectives of the project, regardless of who pays. Costs of past activities and projects are considered sunk costs and are not included in project cost calculation. Consider the following:

a) Only those costs that change between the no-treatment and treatment alternatives should enter the economic analysis. Project costs should be identified by amount and time of occurrence. Future costs, as might be associated with a treatment strategy requiring multiple insecticide applications, must be discounted to their present values.

b) Some project costs cannot be known in advance with certainty. An example of an uncertain cost is that associated with an insecticide spill. Such an event would require cleanup costs. Include expected costs of an uncertain event whenever practical and where sufficient information exists to quantify both the probability and cost of the event. Compute expected costs by identifying the range of outcomes for chance events, determining the cost associated with each outcome, and weighing this cost by the probability or liklihood of the outcomes' occurrence.

c) Economic efficiency decision criteria. Compute and display present net value (PNV) and benefit-cost ratio (B/C) for each suppression alternative. For a detailed discussion of the construction and use of these efficiency measures, see FSH 1907.17, Section 15.

Treatment Effectiveness

Pest population resurgence and reinvasion of a treated area will reduce the effectivness of a pest control effort. Uncertainty surrounding control effectivness can be dealt with either by incorporating effects due to resurgence and/or reinvasion directly into the resource impact projections, or by analyzing a strategy of multiple control treatments.

Discount Rates

Discount all future costs and benefits to their present value. Use 4 percent and 7.125 percent discount rates. Additional discount rates may be used for sensitivity purposes. See FSM 1971.71 for further discussion of discount rates.

Base Year For Analysis

Use the year in which the analysis is being conducted as the base year for all economic costs and benefits.

Stumpage Prices

Use stumpage prices from applicable Forest Plans for National Forest System (NFS) lands. Use local price data for non-NFS lands. If reliable local data are not available, use Forest Plan data for non-NFS lands. For the first decade of the analysis, recent timber price data may be substituted for Forest planning values if the Forest planning values differ substantially from recent timber sale prices. All volume impacts beyond the first decade will be valued at the long-term prices used in Forest Plans.

Real Cost And Price Projection

Use the same real price and cost projections that are used in the Forest Plans.

APPENDIX E

Economic Analysis Of Commercial Timber Impacts In The Pacific Northwest Region

This appendix describes the methods for specific project environmental assessment economic analysis of budworm effects. The objective of an economic analysis is to provide land administrators with information to help judge the relative economic merit of alternative forest protection measures set forth by this environmental analysis. Commercial timber production is the primary focus of attention.

Economic Efficiency Analysis

The purpose of an economic efficiency analysis is to estimate the economic returns associated with alternative forest resource protection strategies proposed for the current western spruce budworm infestation in Oregon and Washington. The efficiency analysis is conducted only for those costs and benefits that can be reasonably expressed in quantitative terms. The evaluation will produce criteria to: (1) judge the economic merit of alternative management strategies for each analysis unit; (2) establish the most efficient level of funding; and (3), if treatment funds are insufficient to exhaust all economically viable investment prospects, provide a basis for selecting the best prospects.

The economic analysis is conducted in accordance with procedures outlined in the Forest Service Manual, Title 3400-Forest Pest Management. According to this method, the No-action Alternative is selected as the baseline against which all other alternatives are compared. Each action alternative affords some measure of protection against forest resource output losses or other undesirable impacts effected by a western spruce budworm outbreak. The value (as expressed in 1987 dollars) of resource losses averted, minus the value of any adverse resource consequences, constitutes the benefits of investing in a pest management alternative. Costs are measured by the value of resources expended in carrying out a management alternative. Once measured for a particular protection investment prospect, benefits are weighed against costs to evaluate its economic viability either on its own account, or relative to competing protection alternatives.

Some forest resources are not exchanged in formal markets and, therefore, have no established market value. If these resources are impacted by the current infestation, other valuation processes will be employed. Among these will be qualitative assessments of value in relation to land management objectives.

Economic Efficiency Measures

The cost-benefit analysis provides two measures for comparing the economic efficiency of the forest protection project alternatives: present net value and benefit-cost ratio. These efficiency measures are prescribed by Section 3422 of the Forest Service Manual. Present net value (PNV) represents the difference between discounted project benefits and costs. The benefit-cost ratio (B/C) is defined as the ratio of present value of benefits to present value of costs. Present value of either benefits or costs is determined by discounting all future values according to the prescribed discount rate(s).

Discount Rates

Present value of benefits or costs is determined by discounting all future values according to the prescribed discount rate(s). The discount rates used in Forest Service evaluations are consistent with those used in long-term Forest planning as outlined under Title 1971 of the Forest Service Manual. The primary rate is 4 percent. To test the sensitivity of the results to higher discount rates, values of 7 1/8 and 10 percent are used.

Resource Benefit

Budworm management alternatives are evaluated relative to the No-action Alternative. Management alternatives have the potential to produce both positive and negative resource benefits. Costs arise from project expenditures on budworm control activities

and on measures taken to mitigate any adverse resource impacts which might occur during the course of a control project.

A variety of forest resources may be impacted by a budworm outbreak and the management strategies used to control it. These resources range from fiber production, wildlife habitat, and fisheries to the visual condition of the forest. General economic analysis limits its consideration to those resources that are identified by the Interdisciplinary Team to be major and common considerations of land managers and the public. Localized issues and impacts are addressed separately.

The major quantifiable resource benefit under the treatment alternatives considered is the gain in wood fiber production resulting from measures taken to control budworm activity. Both stand growth and budworm damage models are combined to project fiber production with and without budworm impacts over a range of resource conditions and management prescriptions. The difference in volume and timing of fiber production under these growth scenarios provides the basis for determining fiber production benefits. This appendix outlines the data and methods employed in determining fiber production benefits of a treatment alternative.

Treatment Costs

The major cost item in the cost-benefit analysis is that associated with application of biological insecticides. For some analysis units, two applications may be necessary to achieve projected levels of benefits.

Whether a second application is necessary for a particular analysis unit depends upon the level of sustained effectiveness achieved by the first application and the number of years remaining in the infestation. Therefore, per-acre protection costs may exceed the cost of a single treatment for newly infested areas.

Many other factors may influence the final per-acre cost of treatment. These include items such as contract specifications, market conditions, and method of insecticide application. For sensitivity testing, the economic results to variations in the cost of treatment, several cost scenarios are analyzed.

Decisionmaking Under Uncertainty

A degree of uncertainty surrounds many aspects of the decision environment covered by this environmental analysis. Type, magnitude, timing, and quality of budworm-caused physical resource impacts can only be approximated. Insufficient data exists to make accurate point estimates. Critical economic data necessary for valuing resource impacts, such as current and future stumpage prices, are continually undergoing revision. This uncertainty extends as well to the level of success achievable by the proposed forest resource protection measures.

Each project-specific environmental analysis takes a step toward providing the land administrator with information regarding the economic implications of major uncertainties. This is accomplished by evaluating the economic efficiency measures over a range of values on the uncertain variables. Through this process, it is possible to explore the degree to which the action selected on the basis of the decision criteria (e.g., a B/C equal to 1) is sensitive to variations in the uncertain variables. If the decision is not sensitive to plausible variations, the decisionmaker can feel comfortable that a correct decision has been made.

If the decision tends to change with only minor variations in the uncertain variable, the decisionmaker should be less certain that a correct choice can be made. In this latter situation, the land administrator may wish to weigh more heavily other criteria in making his decision.

Analysis Unit and Stand Evaluation

An analysis unit (AU) delineates an area, based on land management and entomological considerations, where a decision is to be made in regard to the forest protection alternatives. The uniqueness of individual analysis units requires that each be evaluated with regard to specific resource characteristics. For this reason, resource impacts are identified and evaluated by AU.

Economic evaluation of timber impacts is based upon average stand components. This procedure conforms to Section 3422 of the Forest Service Manual. The particular application of stand analysis utilized here allows for economic sensitivity to differences in stand composition. For each pest management alternative, an evaluation of economic benefits and costs is made for the several average stand categories. These categories express differences in stand structure, management intensity, age structure, host composition, species group, land manager, management philosophy, harvest scheduling, and local stumpage price variations.

Total AU benefits are determined by aggregating the benefits of treatment for all stands within an analysis unit. Total AU benefits for each forest protection alternative are then compared to the cost protection to determine two measures of economic efficiency: present net value and benefit-cost ratio.

Major Assumptions

Selection of base data, impacts to be included in the analysis, valuation procedures, and other facets of the economic evaluation requires making several assumptions. Assumptions are simplifications of the extremely complex forest management and environmental setting of the budworm infestation, and are necessary to carry out this analysis.

No attempt is made to exhaust all assumptions underlying the evaluation. Many are implicit in the analysis. An attempt is made to document major assumptions made to address specific problems presented by the analysis. While most appear in this section, others are stated in the treatment of related topics.

The following assumptions are based on input from land managers and entomologists. They are a necessary basis for performing the economic evaluation:

1. Entomological units reflect area delineations which afford substantial natural checks to pest immigration. Analysis units which depart from the entomological unit concept will introduce a higher risk to reinvasion.

2. Suppression efforts will be effective in reducing budworm populations to endemic levels. However, there is a risk of resurgence within the time period of the current regional infestation.

3. The timing and damage of subsequent regional budworm outbreaks will be unaffected by the forest protection alternatives selected.

4. Preliminary fiber impact estimates indicate their magnitude will not be sufficient to influence forest management activity schedules. The timing of volume impacts are assumed to be determined according to existing harvest schedules.

5. Opportunties for salvaging budworm-induced tree mortality are expected to be limited.

Stumpage Prices and Projections

Future stumpage prices can significantly influence the value of fiber impacts. Because most timber impacts are not expected to be realized immediately, a need exists to project stumpage prices to the appropriate points in time. These projections are made from a baseline. Because of variations between locations and ownerships, baseline stumpage prices per thousand board feet (MBF) for eleven major species are computed for each landownership area within the scope of the current infestation. Stumpage prices also are scaled to reflected relative differences in value associated with tree diameter.

National Forest stumpage prices are based on a 5-year constant dollar average for the time period considered within their respective planning processes. On private ownerships and other public lands, prices are based upon 5-year County data. For Oregon, these estimates are made by the Oregon State Department of Forestry from data made available by the Oregon State Department of Revenue. Estimates for Washington are provided by the Washington Department of Natural Resources and Boise Cascade Corporation.

Historically, the value of stumpage in the Pacific Northwest has increased over the long term at a rate faster than increases in the general price level. Estimates of historical real annual stumpage price increases range from close to zero, to the teens, depending upon species, time period, location, and estimation methodology. For the future, it is unlikely that a rate of real stumpage price increase can be forecast with certainty. For a particular individual, some rates will seem more likely to occur than others. Between individuals there will probably be greater agreement on what the future will not hold than the likelihood of possibilities the future could hold.

All this uncertainty makes the task of conducting the economic analysis and providing decisionmakers with meaningful information quite difficult. The approach taken here is not to attempt to settle upon a specific scenario for future stumpage price increases before conducting the analysis. Instead, economic results for four price-increase scenarios are presented. These are judged to span, with considerable certainty, the most likely range of outcomes over the long term.

Treatment and Protection Costs

A distinction is made between treatment and protection costs. This disparity figures prominently in determining the economic efficiency criteria. Total expected protection costs over the life of the outbreak may exceed initial treatment costs. The magnitude of the difference will depend upon the projected need for treatments later in the infestation. The expectation of incurring future treatment costs is based upon the proportion of acres in an analysis unit that have been infested less than 4 years. A unit which has been infested for 4 or more years in its entirety, is projected to need only one treatment before the end of the infestation. Recently infested units are projected to need two treatments to effect adequate protection until the outbreak collapses. Units which have a mixture of acres at different years of the infestation are projected to need a second treatment with success proportional to the number of acres that are newly infested.

Total protection costs are used in the computation of economic efficiency statistics: present net value (PNV)

and benefit-cost ratio (B/C). Where multiple treatments are expected, or have a chance to be applied for a particular analysis unit, total treatment costs will be computed.

APPENDIX F

Human Health and Environmental Risk Assessment for the Use of Insecticides and a Biological Control Agent in Western Spruce Budworm Suppression Program Conducted by the USDA Forest Service in Washington and Oregon

Prepared for the Forest Service under Contract
Number 53-3187-4-22

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Section 1

INTRODUCTION

PURPOSE

The purpose of this analysis is to assess the risks to human health and the environment (effects on fish, wildlife, and other nontarget organisms) of using three chemical insecticides (carbaryl, malathion, and acephate) and a biological control agent, Bacillus thuringiensis (B.t.) for controlling western spruce budworm on National Forest System lands in USDA Forest Service Region 6 (Washington and Oregon). This risk assessment is a supplement to the Forest Service Environmental Impact Statement (EIS) on suppression of western spruce budworm. The EIS analyzes the environmental impacts of using various alternatives for suppressing western spruce budworm in the Pacific Northwest.

The risk assessment also addresses the human health and environmental risks of a number of chemicals (e.g., the insecticide carrier diesel oil and the formulation ingredients, kerosene and mineral oil) associated with the application of the insecticides and the biological control agent. The analysis also considers N.-nitrosocarbaryl, a carcinogenic metabolic product of carbaryl, that may form in the stomach after oral exposures; malaoxon, a metabolic product of malathion; and methamidophos, a toxic degradation product of acephate.

OVERVIEW OF THE RISK ASSESSMENT

The risk assessment examines the potential health effects to all persons who might be exposed to any of the insecticides and associated chemicals as a result of activities related to spruce budworm spray programs. People potentially at risk are considered to belong to two groups. The first group--workers--includes applicators, supervisors, and other personnel directly involved in the application of insecticides. The second group--the public--includes forest visitors or nearby residents who could be exposed through the drift of insecticide spray droplets, through contact with sprayed vegetation, or by eating food items, such as berries growing in or near forests, game animal meat or fish containing insecticide residues, or by drinking water that contains such residues.

The risk assessment also considers effects on wildlife and aquatic species from the control insecticides by comparing estimated exposures to lethal levels found in laboratory studies.

The analysis of the potential human health effects of the use of insecticides for spruce budworm suppression was accomplished using the methodology of risk assessment generally accepted by the scientific community. In essence, the risk assessment consists of comparing doses people may get from applying the insecticides (worker doses) or from being near an application site (public doses) with doses shown to cause no observed adverse effects in tests on laboratory animals.

A number of factors contribute to the uncertainty in this process of judging risks to human health from laboratory animal studies. First, the reference

animals, particularly rats and mice, in which dose levels produce no observed effects. To allow for the uncertainty in extrapolating from these no-observed-effect levels (NOEL's) in laboratory animals to levels deemed acceptable for humans, safety factors are used. The generally accepted factors (NRC, 1986) are 10 for moving from animals to humans (between species variation) and another 10 to account for possible variation in human responses (within species variation). This 10 times 10, or hundredfold, safety factor means that the laboratory NOEL dose reduced one hundredfold would normally be considered an acceptable or reasonably safe dose. In this risk assessment, a margin of safety (MOS) or "hazard level to exposure level" ratio has been calculated for each estimated dose by dividing the animal NOEL by the estimated dose. The computed MOS is then compared to the hundredfold safety factor to judge the risks of toxic effects.

A second area of uncertainty lies in evaluating the risk to humans of exposures that may occur once or perhaps a few times in a person's lifetime (accidental worker doses and all doses to the public fall in this category) by comparing those human doses to levels of the chemical that produced no ill effects in laboratory animals even though the animals are exposed every day of their lives. This risk assessment uses the MOS approach discussed above in comparing one-time human doses to lifetime animal doses in all of these cases even though this leads to an exaggeration of the risks.

A different approach is used to assess the risks to humans of chemicals that may cause cancer or heritable mutations because they are assumed to have no comparable margin of safety, so some risk exists even at extremely low doses. Human epidemiology cannot be used in assessing risk to heritable genetic damage and rodent models are difficult to quantify (Ehling, 1988). In this case, a cancer potency value, expressing the probability of developing tumors at increasing dose levels, is taken from laboratory animal studies and adjusted for the differences in body weight between the laboratory animals and humans. This potency value multiplied by an estimated human lifetime dose provides an estimate of human cancer risk.

A third area of uncertainty involves the estimation of the human doses likely to occur in insecticide use. This risk assessment has been designed to overestimate doses to err on the side of safety. In reality, workers are likely to experience a range of exposures because they work with the chemicals routinely. However, standard safety practices and the use of protective clothing will normally reduce their actual dose levels far below those estimated in this analysis. The same is true of the doses from any spraying or spill accidents that might occur, because the normal procedure would be to wash immediately. In addition, no member of the public is likely to receive as high a dose as estimated in this risk assessment, again because normal safety practice and the remoteness of most treated areas limit the possibility of the public's receiving any dose at all. Furthermore, the public doses estimated here exaggerate the amount they could receive. No insecticide degradation is assumed to occur, the public is not assumed to wash themselves or their food items after a spraying, and they are assumed to consume water that has received insecticide from drift or a spill immediately after the event. Thus, the way in which exposures are estimated and risks evaluated in this risk assessment tend to exaggerate the real risks.

This risk assessment includes analyses of a range of possible exposures--from realistic to extreme--resulting from insecticide application by using three types of scenarios. (1) Typical application scenarios (routine-typical) are used to estimate the doses to workers and to members of the public who may be nearby that may reasonably be expected to occur during routine operations. (2) Worst-case application scenarios (routine--worst case) are used to give very high dose estimates that are not likely to be exceeded except in the case of an accident. (3) Accident scenarios are used to estimate doses to workers and the public that may result from direct exposure to the insecticide spray mix or concentrate, or from drinking water into which a truckload of insecticide mixture or a drum of insecticide concentrate has been spilled.

Structure of the Risk Assessment

This risk assessment employs three principal analytical elements described by the National Research Council (NRC, 1983) as necessary to characterize the potential adverse health effects of human exposures to existing or introduced hazards in the environment: hazard analysis, exposure analysis, and risk analysis. The relationships among these three components are illustrated in Figure I-I.

> Hazard Analysis requires gathering information that is used to determine the toxic profile of each insecticide. Human hazard levels are derived primarily from the results of laboratory experiments on animal models, such as rats, mice, and rabbits, supplemented where appropriate with information on human poisoning incidents, field studies of other organisms, and data on chemical structure. (A fourth analytical element--dose-response analysis--is subsumed under the hazard analysis.
>
> Exposure Analysis involves estimating single and multiple exposures to persons and wildlife potentially exposed to the insecticides, determining the doses likely to result from those estimated exposures, and determining the number and characteristics of persons in the exposed populations.
>
> Risk Analysis requires comparing the hazard information with the dose estimates and examining their probabilities of occurrence to estimate the likelihood and severity of health effects to individuals under the given conditions of exposure.

The discussion that follows describes briefly how each component in the structure was addressed in this risk assessment.

Hazard Analysis

The insecticides being considered by the Forest Service for the western spruce budworm suppression program include acephate, carbaryl, and malathion, and the biological control agent B.t. The hazard involved in the use of each of the insecticides was determined in a thorough review of available toxicological studies. When no studies were identified for a particular toxicity endpoint, for example, mutagenicity, these data gaps were identified; a worst-case analysis for this endpoint is in Section 4. Scientific uncertainty about the results of particular studies also is discussed. The hazard analysis is presented in Section 2.

Exposure Analysis

To estimate the potential human exposures to the insecticides, various aspects of the western spruce budworm suppression program of the Forest Service in Washington and Oregon that employ insecticides were examined. The analysis considered the characteristics of the spraying operations (including application methods, application rates, size and configuration of spray areas, project design features, and mitigation measures), the human populations likely to be affected, and the routes of exposure for humans in routine operations and as a result of accidents.

Insecticide Spraying Operations. The insecticides examined in this risk assessment are applied aerially, using fixed-wing or helicopter aircraft. The size of the program may vary in any given year, as described in the EIS. The annual program would involve a limited number of large projects and many small projects, ranging from one to many separate treatment units.

Individual treatment units within a project can range from 50,000 to more than 100,000 acres. The average number of acres to be sprayed by one helicopter in 1 day may be approximately 2,500. Therefore, with an average of 10 pilots flying per day, a total of 25,000 acres may be sprayed in 1 day. However, no more than 5,000 acres within a single watershed would be sprayed in 1 day.

The area treated with various insecticides in 1985, the last time a major spray effort occurred, was approximately 500,000 acres, less than 2.3 percent of the possible 21,746,000 acres of National Forest System land in Region 6. The parent EIS and Section 3 of this risk assessment contain further details about these operations.

Affected Populations. In calculating the potential doses to persons at risk from insecticide applications, two populations were considered: workers and the general public. The workers included personnel directly involved in the spray operations: the batch truck operator, mechanics/laborers, load checkers, spray pilots, observation pilots, aerial observers, ground observers, the spray assessment crew, and the biological evaluation crew. The public included forest visitors and nearby residents who may be directly exposed to insecticide as a result of drift, by contact with vegetation with insecticide residues, or by being accidentally sprayed. The public may be indirectly exposed by eating food or drinking water containing insecticide residues.

Routine Exposure Scenarios. This risk assessment examines the health effects of exposure to an individual insecticide treatment, as well as the cumulative effects of exposure over a number of years. To represent the range of doses under normal operating procedures, routine-typical and routine-worst case application scenarios were used. For members of the public, the scenarios involved exposure from various routes, including oral (eating meat, fish, berries, or garden vegetables or drinking water), dermal (vegetation contact and drift exposure), and inhalation (drift exposure). Cumulative exposures to hypothetical hunters and fishermen from several exposure routes also were calculated.

Worker exposures were estimated by task. Tasks included pilot, mixer/loader, ground-based observer, card checker, and efficacy evaluation team member.

Cumulative lifetime doses were estimated for the analysis of lifetime cancer risk by using information on average and maximum treatment days per year and on average and maximum number of years exposed for workers and for the public. Although little data is available, synergistic effects and exposures to mixtures of insecticides also were evaluated.

Accident Exposure Scenarios. Because all human activities involve the possibility of error, the use of insecticides in western spruce budworm suppression involves the possibility that humans may inadvertently receive unusually high exposures to the insecticides because of accidents.

To examine the potential health effects that could occur in an accidental situation, a number of accident scenarios were analyzed. Exposures analyzed included direct aerial application of insecticide on a person, spills of concentrate or insecticide mix on workers during mixing and loading, spills of insecticide into drinking water supplies, and direct spraying of garden vegetables.

Risk Analysis

Human health risks of the western spruce budworm suppression program were evaluated by comparing the doses of workers and the general public calculated for routine operational and accident exposure scenarios to the laboratory-determined toxicity levels described in the hazard analysis.

Risk of acute and chronic threshold effects is evaluated by comparing estimated doses to toxicity reference levels derived from NOEL's in laboratory animal studies, using a calculated MOS. Risk increases as the estimated dose approaches the laboratory toxicity level, that is, as the MOS decreases.

Nonthreshold risk, that is, the potential for these insecticides to cause cancer and mutations, was evaluated differently than threshold risk. The risk of cancer at a given level of exposure, based on the estimated average daily exposure over a 70-year lifetime, was derived for each insecticide from laboratory animal data on tumor incidence at increasing dose levels. These data were corrected for species differences, and the risk of cancer was calculated for various categories of people who may be exposed to the insecticides through various routes.

The risks of heritable mutations are discussed based on the weight of evidence from available test data on bacteria, yeasts, plants, mammalian cells in culture, and whole animals. When no test data are available for an insecticide, a worst case assumption is made that the insecticide is mutagenic, and that risk is then based on the insecticide's estimated cancer risk. This approach is discussed in detail in a later section but assumes that genotoxic agents would be detected as carcinogens from lower exposures than would be required to induce heritable damage in germ cells.

Cumulative risk for individuals is discussed in terms of lifetime exposures to a given insecticide for workers and for members of the public. Risk of synergistic effects is discussed in terms of the available evidence of enhanced toxicity in mixtures of two or more insecticides. Risk to more highly sensitive individuals who may be affected at extremely low exposure levels is

discussed qualitatively in terms of the likelihood of a sensitive individual being exposed.

Worst-Case Analysis Requirements

As indicated earlier, this document is a supplement to the Forest Service EIS, and has been prepared pursuant to the requirements of the National Environmental Policy Act (NEPA) and the Council on Environmental Quality (CEQ) regulations for implementing NEPA.

Data Gaps

This risk assessment identifies a number of information data gaps, including the following:

- o Field studies on exposure to workers for the three insecticides.
- o Information on public exposure to forestry-use insecticides.
- o Field data on residue levels in plants and animals most likely to be found in and around treatment areas for some of the insecticides.
- o Mutagenicity study data for malathion (chromosome aberration) and carbaryl (DNA damage).
- o Teratogenicity study data for malathion and reproduction study data for acephate and malathion.
- o Chronic rat and dog toxicity and mouse oncogenicity study data for malathion.
- o Toxicity information on the synergistic effects from exposure to more than one insecticide.
- o Toxicity information on the cumulative effects from exposure to forestry-use insecticides, other pesticides, and/or other chemicals.
- o Toxicity, infectivity, and exposure information for B.t. (var. kurstaki) to supplement the data from the history of its use.

These information gaps are important in deciding what is the best alternative for action; however, the cost of obtaining this information is an important consideration.

The following are the estimated costs to fill the specific data gaps listed above (Hazelton, 1988):

- o Worker exposure studies would cost approximately $200,000 per chemical.

- o No acceptable protocol is available for measuring all of the various routes of exposure of the public, but these studies would be more expensive than the worker exposure studies.

- o The cost of measuring residues in plants and animals would be between $50,000 and $100,000 per chemical, per plant or animal.

- o The mutagenicity and chromosomal studies for malathion and carbaryl would cost approximately $75,000 per chemical.

- o The teratogenicity study on malathion would cost approximately $60,000.

- o The reproduction study on acephate would cost $150,000.

- o The rat and dog chronic toxicity tests for malathion would cost approximately $400,000.

- o The mouse oncogenicity study for malathion would cost between $350,000 and $400,000.

- o Synergism studies would be extremely expensive because of the great number of tests that would be necessary; there are six combinations of the three chemical insecticides if studied two at a time.

- o The costs of toxicity and infectivity studies on B.t. are not available but should be of the same order of magnitude as the chemical tests.

The overall cost of conducting the studies to fill the data gaps is considered exorbitant for the limited funds available to the Forest Service. In addition, the time necessary to perform and evaluate most of these tests is more than 2 years and would seriously delay the continuation of the western spruce budworm suppression program. Many of the desired toxicological studies have already been requested by EPA, and the results of these studies will be considered when they become available. In addition, both agencies have ongoing research and monitoring programs to examine various aspects of insecticide treatment, and these results will be considered as they become available.

Because the cost of filling the data gaps is considered exorbitant, a worst-case analysis was conducted for those areas where information is unavailable or where there is uncertainty. The worst-case scenarios involving routine insecticide application operations consist of those combinations of parameters, such as treatment unit size, duration of exposure, application rate, application equipment, and meteorological conditions, that give the highest reasonable exposure value. Extreme exposures due to accidents were also evaluated, including those that result from direct spills of concentrate on workers' skin, the direct spraying of an individual, and contamination of a public drinking water supply by an insecticide spill.

The worst-case analysis for the mutagenicity of an insecticide for which there are no data or where there are some positive short-term tests for mutagenicity assumed that the insecticide could cause heritable mutations. In establishing genetic risk for these compounds using a worst-case scenario, the risk of heritable mutations was assumed to be no greater than the risk of cancer for a

given insecticide. This assumption is based on analysis of existing data for chemicals with both cancer and heritable mutation biassays.

The worst-case analysis for insecticides that had either positive cancer studies or for which there is scientific uncertainty assumed that these chemicals could cause cancer. A conservative cancer potency value for a chemical was computed by using the highest rates of tumor formation found in the available animal studies. A conservative model for estimating human cancer rates from tumor rates in laboratory animals also was used. The worst-case analysis for synergistic effects assumed that these effects could occur. The probability of these effects occurring was considered low.

EPA has identified the data gaps shown in section 2, Table 2-11, in accordance with the registration guidelines under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended. Although there are data gaps or areas of uncertainty for some of the insecticides in this risk assessment, there is a large body of existing data useful for predicting the behavior and toxicity of these insecticides, including the following:

- o Worker exposure studies with EPN (ethyl p-nitrophenyl thionobenzene phosphate) insecticide.

- o Studies on drift of the insecticide trichlorfon.

- o Residue information for the insecticides in plant and animal tissues.

ORGANIZATION OF THIS RISK ASSESSMENT

Section 2, the hazard analysis, summarizes and discusses the toxic properties of each insecticide, including the cancer potency of the known or suspected carcinogenic insecticides. Section 3, the exposure analysis, describes the methods used to estimate levels of exposure and resultant doses to workers and the public, and presents summary tables and discussions of estimated acute and long-term doses. Section 4, the risk analysis, presents the comparison of the results of the exposure analysis with the toxic effect levels set forth in Section 2. Section 4 also discusses cancer risk, given estimated lifetime doses to workers and the public. Appendix A presents a discussion of the environmental fate properties of the insecticides. Appendix B discusses the analysis of the risk of heritable mutations.

HAZARD ANALYSIS

- o Identify what kinds of health effects have been observed under experimental laboratory conditions and at what levels of exposure
- o Identify any health effects that have been observed in humans
- o Determine median lethal dose (LD_{50}) for acute effects from laboratory rat study
- o Determine lowest no-observed-effect

EXPOSURE ANALYSIS

- o Identify people exposed
- o Identify routes of exposure
- o Estimate how much each person would receive by each exposure route using both realistic and worst-case scenarios
- o Estimate frequency and duration of exposure
- o Calculate doses

levels (NOEL's), if possible, for general chronic toxic effects, reproductive effects, and birth defects
- o Determine whether the insecticide has the potential to induce cancer or mutations
- o Identify information data gaps in toxicity information

RISK ANALYSIS

- o Compare doses to NOEL's and LD_{50}'s and discuss probability of acute and chronic effects (including birth defects) for routine through worst-case scenarios
- o Conduct worst-case analysis for cancer risk
- o Conduct worst-case analysis for risk of heritable mutations

HAZARD ANALYSIS

PURPOSE

The purpose of this hazard analysis is to determine the potential hazard to humans and nontarget organisms from four insecticides, three formulation inert ingredients, and a pesticide carrier considered for use in Region 6 for the suppression of western spruce budworm. This section presents available toxicological information for the three chemical pesticides malathion, carbaryl, and acephate, and a microbial pesticide, *Bacillus thuringiensis*.

Because carbaryl is commercially formulated (as Sevin 4-Oil) with kerosene and because diesel oil is used as a carrier in the application of Sevin 4-Oil, the hazards of kerosene and diesel oil also are addressed. (Petroleum oils and diesel oil are listed by EPA as inerts of toxicological concern.) Mineral oil, a formulation ingredient in *Bacillus thuringiensis*, is not an inert of concern and will be addressed briefly in this report. The hazards associated with methamidophos, a degradation product of acephate and N-nitrosocarbaryl, a metabolic reaction product of carbaryl, also are analyzed in this section.

The first part of this section describes the sources of toxicity information used in the hazard analysis. The second part explains the terminology concerning laboratory toxicity testing used later in describing the toxic properties of the insecticides. Scientific and technical terms are defined in the glossary. The remainder of the section presents the hazards to humans, wildlife and beneficial insects, and aquatic organisms.

SOURCES OF TOXICITY INFORMATION

The toxicity of the three insecticides (malathion, carbaryl, and acephate) to laboratory animals, humans, wildlife, and aquatic species is described in detail in the background statements prepared for the Animal and Plant Health Inspection Service (APHIS) by Roy F. Weston, Inc. (Dobroski, 1985; Dobroski and Lambert, 1984; Lambert, 1985). Most toxicity data presented for *Bacillus thuringiensis* were obtained from a background statement prepared for the Forest Service by Mitre Corp. (Sassaman, 1987). Toxicological data for diesel oil and kerosene were obtained from a background statement that LABAT-ANDERSON Incorporated prepared for the Forest Service.

Much of the data on pesticide toxicity have been generated to comply with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended (7 U.S.C. 136 et sec.), which establishes procedures for the registration, classification, and regulation of all pesticides, including insecticides. Toxicity levels and related information from the series of studies submitted for registration are compiled by EPA in summary tables, called tox one-liners, which are available on request from EPA's Freedom of Information Act Office. EPA has compiled "science chapters" on carbaryl and acephate, which also are available from EPA.

An extensive literature search was funded by the Forest Service to ensure that all of the relevant available information was used in this risk analysis. That search was updated to make the document current for information available as of May 1, 1988. Whenever possible, studies that have been reviewed and evaluated

by EPA were used to select toxicity reference levels for use in this risk assessment. In no cases were studies used that have been determined invalid by EPA.

HAZARD ANALYSIS TERMINOLOGY

Judgments about the potential hazards of pesticides to humans are necessarily based on the results of toxicity tests on laboratory animals. These toxicity test results are supplemented by information on actual human poisoning incidents and effects on human populations when they are available. The discussion of laboratory toxicity testing that follows is extracted from Doull et al. (1980), Hayes (1982), and Loomis (1978).

Laboratory Toxicity Testing

Test Animal Species

Laboratory test animals function as models of the likely effects of the pesticides in humans. Ideally, the selected test animal should metabolize the compound the same as a human, and should have the same susceptible organ systems. On a body-weight basis, humans generally are more susceptible to the compound's effects than experimental animals, by an approximate factor of 10 (Doull, 1980). Results of such tests then can be directly extrapolated to humans, with some adjustment for differences in body weight and body surface area. Although no test animal has proved to be ideal, a number of species, in particular, rats, mice, rabbits, hamsters, guinea pigs, dogs, and monkeys, have proved to be consistent indicators for certain types of toxicity tests, routes of administration, and types of chemicals.

Toxic Endpoints and Toxicity Reference Levels

Toxicity tests are designed to produce specific toxic endpoints, such as mortality or carcinogenicity, and toxicity reference levels, such as a no-observed-effect level (NOEL). In addition to the test animal used, toxicity tests vary according to duration of exposure, route of administration, dose levels, frequency of exposure, number of test groups, and number of animals per group. Toxicity tests also vary according to whether the effect in question is assumed to be a threshold or nonthreshold effect.

Threshold and Nonthreshold Effects

The objective of most toxicity testing is to establish threshold levels that can be adjusted by a safety factor to establish acceptable levels of exposure. Threshold levels are levels of exposure that produce no toxic effects but, when exceeded, may produce an adverse effect in the test organism. Examples of toxic effects include pathologic injury to body tissue; a body dysfunction, such as respiratory failure; or a toxic endpoint, such as birth defects. Chemicals are generally thought to possess no such threshold level for cancer and mutations; thus, these toxic endpoints may occur (with a certain level of probability) even in the presence of extremely small quantities of the substance.

Duration of Toxicity Tests

The duration of exposures in toxicity tests range from short-term acute tests, to longer subchronic studies, to chronic studies that may last the lifetime of an animal. Acute toxicity studies involve administration of a single dose to each member of a test group (either at one time or in a cumulative series over a short period, usually less than 24 hours). Subchronic toxicity studies, used to determine the effects of multiple doses, usually last from 3 to 90 days, but generally less than one-half of the lifetime of the test animal. Most subchronic toxicity tests last 90 days. Chronic studies, also used to determine the effects of multiple or continuous doses, normally last 2 to 7 years depending on the test species, but generally more than one-half of the test species' lifetime.

Routes of Administration

Routes of administration include oral by means of gavage (forced into the stomach with a syringe through a plastic tube) or fed in the diet; dermal (applied to the skin); inhalation (through exposure to vapors or aerosol particles); and parenteral (injection other than into the intestine), such as subcutaneous (injected under the skin), intrperitoneal (injected into the abdominal cavity), and intravenous (injected into a vein). The selection of the route of administration of a particular test material is based on the probable route of exposure to humans. Oral, dermal, and inhalation doses most nearly duplicate the likely routes of human exposure. Parenteral doses are used in testing drugs but are not widely used in pesticide toxicity testing because they bypass the test animal's natural protective mechanisms and sensitive systems such as the skin and lungs.

Dosage units may be expressed in several ways, which include the following: amount of test material based on the body weight of the organism (i.e., milligram of test material per killigram of body weight), as parts per million (ppm) in the diet of the test organism, or in milligrams per liter (mg/L) in the air the organism breathes or in the water the organism drinks.

Dosing Levels

Dosing in longer term studies is generally administered in the diet, with specified amounts in parts per million in the food. The known weight of the test animals over the test period is used to convert parts per million in the diet to milligrams of chemical per kilogram of body weight per day (mg/kg/day) for extrapolation to humans. In most chronic toxicity studies, at least three dosing levels are used in addition to a zero-dose or control group. In general, the control group animals are administered the vehicle used in the test material administration. In a dietary study, the basal feed would serve as the vehicle. Test organisms are typically dosed in groups of 8 to 50 animals per sex.

Types of Toxicity Studies

Acute Toxicity Studies

Acute toxicity studies are used to determine the toxicity reference level, known as the median lethal dose (LD_{50}), which is the dose that kills 50 percent of the test animals. The lower the LD_{50} indication of potency, the greater the toxicity of the chemical. The LD_{50} toxicity categories used in

this risk assessment are those of the EPA classification system that uses rat LD_{50}'s, as shown in table 2-1. Because mortality is the intended toxic endpoint, dose levels usually are set relatively high in acute studies. Overt indications of toxicity exhibited by the animals are recorded throughout the study, and tissues and organs are grossly examined for abnormalities following sacrifice at the end of the test. The rat is most commonly used for oral LD_{50}'s. Rabbits are used most often to determine dermal LD_{50}'s.

Because death represents the extreme toxic consequence for judging possible effects from the use of pesticides, the policies of regulating agencies regarding acceptable intake levels of these chemical compounds are most often based not on acute studies, but rather on toxicity tests designed to find the dose level that produces no effects in the animal species tested.

Subchronic Toxicity Studies

Subchronic studies are designed to determine the toxicity reference level called the no-observed-effect level (NOEL), which is the highest dose level at which no toxic effects are observed. Subchronic studies, normally employing lower dose levels than acute studies, provide information on systemic effects, cumulative toxicity, the latency period (the time between exposure and the manifestation of a toxic effect), the reversibility of toxic effects, and appropriate dose ranges to be used in chronic tests. The adverse effects may include overt clinical signs of toxicity, reduced food consumption, abnormal body weight change, abnormal clinical hematology or chemistry, and/or macroscopic or microscopic abnormalities in the test organism's tissue.

Testing of a biological pest control agent includes assays focused on identifying the possible infectivity of the microbe employed. Cultures are introduced into selected sites in the test species (e.g., gastrointestinal tract, brain, respiratory tract). Any evidence of toxicity or infection resulting in mortality to the test species would trigger attempts to isolate the agent from the treated organism.

Chronic Studies

Chronic studies, like subchronic studies, can be used to determine systemic NOEL's. If all other variables of the test are equal, the longer the study from which the NOEL is derived, the more confidence there is in the predictive accuracy of the resulting value. However, chronic studies are even more important in identifying chemicals that produce doses that produce delayed toxicity, such as carcinogenicity.

Teratogenicity Studies

Teratogenicity studies (also called developmental studies) determine the potential of a chemical to cause malformations in an embryo or a developing fetus between conception and birth. These studies are generally performed on rats or rabbits, and they may be conducted over several generations. The rat is are monitored for functional as well as structural deformities. A range of doses is employed to determine the teratogenic NOEL.

Reproductive Studies

Reproductive toxicity studies are conducted to determine the effect of a chemical on reproductive success, as indicated by fertility (production of reproductive cells), fetotoxicity (direct toxicity to the developing fetus), and survival and weight of offspring. Other end points, such as teratogenicity, can be assessed, but these are the most common.

These tests are performed at doses similar to those used in teratogenicity studies and typically use rats. Both male and female rats are exposed to the chemical for a number of weeks before mating. The number of resulting pregnancies and viable offszpring produced are recorded. Tests may be conducted over two or three generations.

Carcinogenicity Tests

Carcinogenicity tests (cancer studies or oncogenicity studies) are conducted to determine the potential for a chemical to cause tumors when administered to an animal over its lifetime. Testing is normally conducted by placing the chemical in the diet of rats or mice for approximately a 2-year period.

The cancer potency of a chemical is defined as the increase in likelihood of getting cancer from a unit increase in the dose of the chemical. The cancer potency value reflects the probability of getting cancer sometime in a person's lifetime for each mg/kg/day. The cancer potency is derived from tumor data generated in laboratory animal studies.

Several assumptions have been made in estimating cancer potencies. First, it is assumed that any dose, no matter how small, has some probability of causing cancer. This is an assumption based on the nonthreshold hypothesis which postulates that even a single, extremely small dose may be enough to trigger cancer. Second, one of the principal areas of scientific controversy in cancer risk assessment is extrapolating the cancer potency line from the high doses used in animal studies to the far lower doses humans may get. Third, the cancer potency used in the calculation of human risk in this risk analysis is not the maximum likelihood potency value, but the upper limit value of the 95-percent statistical confidence interval.

Mutagenicity Assays

This section describes the use of the results of mutagenicity assays to draw conclusions about the risk of a chemical causing genetic effects. Mutagenicity assays are used to determine the ability of a chemical to cause physical changes (mutations) in the basic genetic material (DNA) of germ cells or somatic cells. Germ cell genetic defects could possibly lead to the passing of defective genetic instructions to offspring. The offspring may develop diseases or malformations or may be predisposed to diseases because of those inherited defects. Somatic cell genetic defects are believed to play a role in the development of certain diseases, particularly cancer.

Genetic diseases and abnormal phenotypes (e.g., congenital anomalies) are produced in humans as a consequence of genetic errors occuring at the gene or chromosome levels (McKusick, 1983, Denniston, 1982). Most humans affected by genetic disease inherited their disease or predisposition for the disease as a pre-existing genetic error (Matsunaga, 1982; Carter, 1977). The same is probably true for congenital anomalies. A small percentage of affected

individuals represent "new" mutations that were not pre-existing in the germ lines of their parents. The specific causes of these "new" mutations are unknown, but they could arise spontaneously or could be induced by natural mutagens (i.e., aflatoxins, background radiation), therapeutic regimens (cancer treatment with agents such as cytoxan or Adriomycin), or from environmental or occupational exposures to mutagenic chemicals (Brusick, 1987).

To date, epidemiological studies of human populations have revealed the existence of more than two dozen human carcinogens but have failed to epidemiologically confirm an agent that could be legitimately classified as a human germ cell mutagen. Consequently, judgments of human genetic risk must be built upon evidence from nonhuman sources and extrapolated to human populations.

According to EPA's guidelines for germ cell mutagenicity risk assessment (Fed. Reg. 51(185):34006-34012, Sept. 24, 1986), mutagenic endpoints of concern include point mutations (submicroscopic changes in the base sequence of DNA) and structural or numerical chromosome aberrations. Structural aberrations include deficiencies, duplications, insertions, inversions, and translocations. Numerical aberrrations are gains or losses of whole chromosomes. Other relevant test endpoints include DNA damage, unscheduled DNA synthesis (UDS), recombination and gene conversion, and sister chromatid exchange (SCE).

The species used in mutagenicity assays range from primitive organisms, such as the bacteria *Salmonella*, *Escherichia*, and *Streptomyces*; the mold *Aspergillus*; the yeast *Saccharomyces*; and the fruit fly *Drosophila*, to more advanced organisms including mammalian species. Tests may be conducted in vivo (within the body of the living organism) or in vitro (on cells cultured outside the body in a petri dish or test tube).

According to Dr. David Brusick of Hazelton Laboratories (see list of preparers), data that might be used in germ cell mutagenicity risk assessments come from mutagenicity studies that can be categorized as follows:

Mammalian germ cell tests. Mammalian model studies for germ cell alterations consist predominantly of tests on rodent models (typically mice) for transmissible effects (specific locus, heritable translocation, and selected dominant genes) and nontransmissible effects (dominant lethal chromosomal aberrations, gonadal DNA damage and repair).

Short-term tests.

- Mammalian model studies for somatic cell alterations--include many of the tests commonly used in genetic toxicology, such as chromosome analysis, micronucleus tests, tests for unscheduled DNA synthesis (UDS), and measurements of DNA adducts.

- Submammalian model studies for germ cell or somatic cell alterations--typical tests in this group are the *Drosophila* sex-linked recessive lethal assay and the *Salmonella* reverse mutation assay (Ames test).

- Mammalian cell in vitro tests--cultured mammalian cells can be screened for all classes of genetic alterations (i.e., chromosome damage, gene mutation, UDS).

Genotoxic Carcinogens. The National Research Council (NRC, 1987) states that there are two broad mechanisms by that chemicals cause cancer by some direct chemical interaction with the DNA structures of the cell or by indirect effects on the cellular environment that increase the tumor yield without direct chemical alteration of DNA. The former are termed genotoxic carcinogens and the latter, epigenetic carcinogens.

EPA describes the use of mutagenicity tests as evidence in judging the likelihood that a chemical is a genotoxic carcinogen. According to EPA's guidelines for carcinogen risk assessment (Fed. Reg. 51(185):33992-34003, Sept. 24, 1986):

> Tests for point mutations, numerical and structural chromosome aberrations, DNA damage/repair, and in vitro transformation provide supportive evidence of carcinogenicity and may give information on potential carcinogenic mechanisms. A range of tests from each of the above end points helps to characterize an agent's response spectrum.
>
> Short-term in vivo and in vitro tests that can give indication of initiation and promotion activity may also provide supportive evidence for carcinogenicity. Lack of positive results in short-term tests for genetic toxicity does not provide a basis for discounting positive results in long-term animal studies.

The methods for cancer risk analysis using animal data have been reasonably well formulated. However, in the absence of rodent cancer data or with negative rodent cancer data, positive results from short-term tests for genotoxicity have been used as justification for considering the chemicals as potential carcinogens. The rationale for such a use of short-term assays rests with the close mechanistic and correlative association between carcinogens and mutagens (Brusick, 1987; Shelby, 1988).

Estimates of cancer potency that are used to assess cancer risk are based on the results of long-term feeding studies indicating tumor induction rather than on the results of short-term mutagenicity assays. An approach that has been suggested by some experts is to develop worst case estimates of cancer risk from cancer studies regardless of whether the studies show significant evidence of increasing tumor incidence with increasing dose. This risk assessment does not adopt this approach because the accepted practice in EPA and the scientific community is to consider only those chemicals with positive tumor evidence as potential human carcinogens.

It is assumed in regard to heritable mutagenicity risk that the cancer tests are the more sensitive toxic endpoint (that is, that no chemical has been shown to be a germ cell mutagen that has not been shown to be carcinogenic at lower doses), and thus cancer bioassays would constitute the worst case estimator of risk. This argument is developed in detail in Appendix B of this risk assessment.

Use of Short-Term Tests to Evaluate Germ Cell Risk

Background. The published EPA guidelines cited above for using short-term test data in assessing mutagenic risk fail to provide methods for quantifying genetic risk estimates. Although the EPA guidelines do provide broad qualitative risk classifications, the guidelines are insufficient to distinguish the risk estimation between two different chemicals that may fall into the same general class. Therefore, Government agencies such as the Bureau of Land Management (BLM) and the Forest Service have no guidelines for conducting quantitative risk assessments for this type of toxicity in order to reach worst case risk estimates, which should be at least semiquantitative.

Each type of genetic toxicology test described above has its particular strengths and limitations. Knowledge of these is important in extrapolating test responses to humans. For example, there may be a tendency to use a positive response from an in vitro assay, for example, to operationally define a tested chemical as a mutagen even when the chemical cannot be shown to be mutagenic in any other test. This use of in vitro data may well be an inappropriate use of such tests. Further extension of these limited positive findings into a presumption of genetic risk is not supported by the available scientific evidence. Appendix B provides a detailed discussion of this topic.

Correlation of Rodent Germ Cell Tests With Short-Term Test Results. Although no chemical has been conclusively established as a human germ cell mutagen, evidence from studies showing chemical-induced mutations in human somatic cells as well as the identification of rodent germ cell mutagens argue that at least some "new" human mutations and their resultant pathologies are likely to be the consequence of environmental exposure to mutagenic chemicals. However, without human data, mammalian germ cell models (i.e., mouse assays) will have to serve as the experimental standard upon which human risk estimates are based (Ehling, 1988). If the logic of inferring human germ cell risk from the results of rodent germ cell tests is acceptable then one can determine the relative predictive accuracy of nongerm cell tests identified in the previous section for identification of germ cell mutagens. Three review articles have summarized the results of such an exercise (Committee 1, 1983; Russell et al., 1984; Bridges and Mendelsohn, 1986). The scientific evidence indicates, however, that no single nongerm cell test is sufficiently accurate to predict the effects that would be obtained from animal germ cell tests. Therefore, the use of isolated positive responses from short-term tests (nongerm cell tests in mammals, submammalian assays, or mammalian cell in vitro tests) to establish genetic risks is not supported by available data and is an inappropriate use of such data. In the absence of rodent germ cell data, a weight-of-evidence approach should be applied when using short-term test results to identify potential genetic hazard.

A Weight-of-Evidence Approach to Germ Cell Mutagenicity Risk. The next approach to the use of the abundance of nongerm cell test (i.e., short-term test) results is to establish a weight-of-evidence approach for collectively evaluating the composite response from all tests conducted on a specific agent.

Several qualitative (EPA, 1986a) and quantitative (Pet Edwards et al. 1985; Brusick et al.; 1986) predictive or weight-of-evidence schemes for mutagenicity data have been proposed. None of these weight-of-evidence schemes has been examined in detail for its concordance with the rodent germ cell data base.

However, it appears necessary to use some type of weight-of-evidence scheme to assemble and evaluate a group of short-term studies.

The weight-of-evidence discussion of the results of mutagenicity assays for the three insecticides in this risk assessment deals with those assays on the basis of 3 broad groups of mutagenicity endpoints: (1) tests for detecting gene mutations, (2) tests for detecting chromosomal aberrations, and (3) tests for detecting primary DNA damage.

Group 1 tests include microbial assays, involving prokaryotic (bacteria) and eukaryotic microorganisms (yeasts, fungus) developed to detect reverse mutations and, to a limited extent, forward mutations. Because many mutagens are inactive before bioactivation (by metabolic activity), bacterial tests may include a bioactivation system, such as an S9-fraction, consisting of microsomal enzymes of rats' or other animals' livers to activate the mutagen. A host-mediated assay is conducted to detect mutagenic effects in microorganisms, such as bacteria, by injecting a culture into the peritoneal cavity of the host (usually mice) to allow for bioactivation of the mutagen in vivo. Other tests useful for predicting gene mutations are the fruitfly sex-linked recessive lethal test, which measures the frequency of lethal mutations; the mouse specific locus test, which detects mutagenicity in germ cells in vivo; and mammalian somatic cell assays in vitro using mouse lymphoma cells, human lymphoblasts, and Chinese hamster ovary cells to detect forward and reverse mutation.

Group 2 tests for detecting chromosomal effects include mammalian cytogenetic assays in Chinese hamster ovary cells in vitro and mice bone marrow micronucleus in vivo. The dominant lethal test in rodents, which determines lethal mutation in germ cells, and the heritable translocation test in mice, which detects the heritability of chromosomal damages, are important tests performed with live animals. Fruitflies and other insects also are used to detect heritable chromosomal effects in vivo.

Group 3 tests for the existence of DNA damage caused by mutagens are based on detection of the damage by biologic processes, such as DNA repair and recombination, which occur after DNA damage. Tests to determine such processes use bacteria, yeast, and mammalian cells in vitro, with or without metabolic activation. Unscheduled DNA systhesis, for example, is ofter used to indicate DNA repair in human cells in vitor. Mitotic recombination and gene conversion indicate DNA damage in yeast, and sister chromatid exchange indicates DNA damage in mouse lymphoma cells, Chinese hamster ovary cells, and human lymphocytes.

The weight-of-evidence approach used in this risk assessment is similar to that of EPA (1986a). This approach places greater emphasis on assays conducted in germ cells than in somatic cells (for detecting heritable mutations), in vivo rather than in vitro, in eukaryotes rather than prokaryotes, and in mammalian species rather than submammalian species. In vivo mammalian systems are considered to be of greater value because of their similarity to human physiology and metabolism. EPA (1986a) classifies the evidence for potential human germ-cell mutagenicity as sufficient, suggestive, or limited, depending on the results of various tests performed. For instance, positive results in even one in vivo mammalian germ-cell mutation test are considered sufficient evidence for potential human mutagenicity of a specific chemical.

Epidemiology Studies

The effects on humans of exposure to chemicals in the environment can be derived from in vivo or in vitro laboratory studies (as described above), reports of clinical observations of isolated exposed individuals (human poisoning incidents), experimental studies in humans, or from direct observations of exposed human populations. The data on humans generally fall into two categories: clinical data on individuals and epidemiological data revealing patterns of disease or death in groups of humans exposed to single agents or to a variety of substances (NRC, 1986). Thus, epidemiology studies are done to investigate the causes of disease in specified human populations by examining relationships between the incidence of particular disease types and factors associated with the disease, such as the use of particular substances in the workplace. One such association is the use of various pesticides by agricultural workers and the incidence of several types of cancer.

Studies conducted by the National Cancer Institute have found that fewer farmers die from cancer than would be expected based on the cancer death rate of the U.S. general population. However, farmers have a higher risk of developing lymphatic and blood-related cancer, including leukemia and cancer of the prostate, skin, and stomach (Blair, 1982; Blair et al., 1985; Blair and Thomas, 1979; Blair and White, 1981, 1985; Cantor, 1982; Cantor and Blair, 1984; Weininger et al., 1987).

Although no single agricultural factor has been consistently associated with increased rates of specific cancer, correlations with insecticide and herbicide use were noted in a number of studies (Blair and White, 1985; Cantor, 1982; Cantor and Blair, 1984; Cantor et al., 1985). In the United States, farmers have a much lower rate of lung cancer than the general population, primarily because of their lower smoking rate (Blair, 1982). However, a cohort study of pesticide-exposed male agricultural workers in the German Democratic Republic (Barthel, 1981) found that they had a significantly higher mortality rate from lung cancer than the general population.

In a cohort study of licensed pesticide applicators in Florida, excess deaths from leukemia and cancers of the brain and lung were observed (Blair et al., 1983). The risk of lung cancer rose with the number of years the applicators had been licensed (Blair et al., 1983). Other studies have found little or no correlation between cancer incidence and pesticide use (Blair and Thomas, 1979; Blair and White, 1981), although factors such as exposure to oncogenic animal viruses have been related to increases in certain types of cancer (Blair, 1982; Blair et al., 1985).

PRINCIPAL TOXIC EFFECTS OF ORGANOPHOSPHATE AND CARBAMATE INSECTICIDES

This section discusses the toxic hazards of the insecticides to humans as indicated by human epidemiological and clinical studies and by studies of effects in laboratory animals.

This discussion of the toxicity of carbamate and organophosphate compounds was extracted from Smith (1987), Cranmer (1986), and Murphy (1980).

Exposure to organophosphates (such as malathion and acephate) or carbamates (such as carbaryl) results in the inhibition of cholinesterase (ChE) enzyme activity, specifically, acetylcholinesterase (AChE). Acetylcholinesterase is responsible for the breakdown of acetylcholine, a neurotransmitter that permits transmission of nerve impulses across the nerve synapse. Inhibition of acetylcholinesterase results in accumulation of acetylcholine and the continual transmission of nerve impulses. The extent of inhibition of ChE caused by a given dose of insecticide is usually expressed as a percent; either a percent of normal activity or as a percent reduction compared to normal activity. The inhibition process is reversible. Organophosphates tend to inhibit ChE for longer periods than the carbamates at a specific dose level, and the effects tend to accumulate so that a sequence of low doses can produce the same effect as a single higher dose. Organophosphates exhibit a pesticide-enzyme binding reaction, which is irreversible. In contrast, the carbamalated enzyme (formed in reaction with carbamate pesticides) is destabilized through biochemical processes in the body. Carbamates are relatively rapidly reversible ChE inhibitors. Organophosphates are generally metabolized, in part, to more active ChE inhibitors, for example, malathion to malaoxon. Carbamates appear to function directly as inhibitors.

Toxic effects of ChE inhibition at low doses in humans include localized effects, such as nose bleed, blurred vision, and bronchoconstriction; and systemic effects, such as nausea, sweating, dizziness, and muscular weakness. Effects of higher doses include irregular heartbeat, elevated blood pressure, cramps, and convulsions. Inhibition up to 40 percent (40-percent reduction in activity) in laboratory animals and humans is tolerated well and may produce transitory, less severe symptoms. In general, a chemical is considered to have an effect if there is 20 percent inhibition as compared to the pretreatment value for plasma, erythrocyte, and brain ChE. Inhibition above 50 percent can lead to much more severe, prolonged symptoms of ChE inhibition. Where a fatal dose of organophosphates or carbamates has been received without emergency treatment (generally by administering the antidote atrophine), death usually occurs within 24 hours.

For the organophosphates, other toxic effects, in addition to ChE inhibition, include delayed neurotoxic effects of phosphate triesters that include nerve cell demyelination and slow, but in general reversible, weakness and flaccidity of the limbs.

Biological pesticides are subjected to tests in addition to the normal toxicity assays used for chemical agents. The microorganisms are evaluated for their infectivity in rodent species following injection into specific sites. Infectivity is an important parameter since exposure to large numbers of the biological agents is possible through spills into the eyes or by inhalation of aerosols into the respiratory tract. It is also possible that accidental ingestion of the agents may occur. The production of the biological agent from large mass cultures may also introduce toxicity concerns because of contamination of the cultures by related pathogenic strains.

HUMAN HEALTH HAZARDS

The toxicological properties of malathion, acephate, and carbaryl, as determined by laboratory toxicity, studies are presented in table 2-2

(threshold effects), table 2-3 (nonthreshold effects), and table 2-4 (mutagenicity assays).

Malathion

Studies in Humans

A 47-day human ingestion study (Moeller and Rider, 1962) resulted in a lowest effect level for blood ChE inhibition of 0.34 mg/kg/day, and EPA has stated that this indicates a ChE NOEL of 0.23 mg/kg/day (EPA, 1988a). Using a ten-fold safety factor and the results of this study, EPA has established an ADI of 0.02 mg/kg/day.

After the aerial application of malathion to a 13,000-square-mile area in the San Francisco Bay area, the occurrence of birth defects and low birth weight was examined from data from local hospitals. This study concluded that there was no increase in incidence of congenital anomalies or low birth weight as a result of the exposure of the population to malathion (Grether et al., 1987).

Neurotoxicity

The principal toxic effect observed in mammals after exposure to malathion is inhibition of acetylcholinesterase, resulting in inhibition of nerve impulse propagation. Malathion itself is only slightly inhibitory; however, its metabolite malaoxon is an active inhibitor. In a study with mice, ChE activity was depressed by malaoxon 25 times more than by malathion (DHEW, 1976). Some studies indicate that conversion of malathion to malaoxon is necessary for any significant amount of anticholinesterase activity to occur. After absorption by the intestine, skin, or lungs, malathion is transported in the blood to the liver, where it is metabolized to nonacetylcholinesterase inhibitors and to malathion's oxygen analog, malaoxon. Malathion and malaoxon are then rapidly detoxified by hydrolysis in the liver and other organs including the brain. The rapid hydrolysis and detoxification of malathion by the esterase enzyme system in humans accounts for its low toxicity in mammals (Dobroski and Lambert, 1984; DHEW, 1976).

Acute Toxicity

Based on an acute oral LD_{50} (median lethal dose) in rats of 370 mg/kg, malathion can be classified as a moderately toxic insecticide (NLM, 1986a). The LD_{50} is, however, species-dependent. For instance, in sheep the oral LD_{50} is less than 150 mg/kg; in guinea pigs, 570 mg/kg; in calves, 80 mg/kg; in cows 560 mg/kg; in hens 200-400 mg/kg; and in dogs between 430 and 600 mg/kg.

Subchronic Toxicity

A 33-day rat feeding study revealed a ChE lowest observed effect level (LOEL) of 1,000 ppm (50 mg/kg/day) for ChE inhibition in erythrocytes (red blood cells) and a ChE NOEL of 100 ppm (5 mg/kg/day) (NRC, 1977). A 4- to 6-week rat feeding study during which males were fed 62 mg/kg/day of malathion and females were fed 68 mg/kg/day resulted in a 50-percent reduction of erythrocyte, plasma, and brain cholinesterase (Craigmill, 1981).

A 90-day dog study by Kenaga (1982, cited in Smith 1987) reported a NOEL of 100 ppm (mg/kg/day) for oral administration of malathion.

Chronic Toxicity

A 2-year rat feeding study during which test animals were exposed to malathion at 100, 1,000, and 5,000 ppm (5, 50, and 250 mg/kg/day) resulted in a 10- to 30-percent reduction of ChE activity at the lower doses. At 5,000 ppm (the highest dose tested), growth retardation, total inhibition of erythrocyte ChE, and a 60- to 95-percent inhibition of plasma and brain ChE was observed (DHEW, 1976).

A second 2-year rat feeding study during which animals were administered malathion at 500, 1,000, 5,000 and 20,000 ppm (25, 50, 250, and 1,000 mg/kg/day) also resulted in decreased ChE activity and body weight reduction. Histological examination of tissues revealed no microscopic abnormalities (DHEW, 1976).

Reproductive Developmental Effects

The dietary administration of 240 mg/kg of malathion to rats for 10 weeks did not affect the reproductive performance of males or females (Kalow and Manton, 1961). The daily intake of 240 mg/kg of malathion reduced the number of newborns surviving to 7 days of age by 50 percent. A three-generation reproduction study during which rats were fed 100, 500, or 2,500 ppm (5, 25, or 125 mg/kg/day) resulted in respiratory distress, reduced fertility, reduced pup weights, and poor survival of pups at the highest dose tested level of 2,500 ppm (125 mg/kg/day) (DHEW, 1976).

Nonthreshold Oncogenicity Effects in Laboratory Animals

The oncogenic potential of malathion and its metabolite, malaoxon, have been evaluated based on three bioassays reviewed by EPA. An 80-week bioassay of mice and rats exposed to malathion did not result in evidence of increased tumor incidence (NCI, 1978). EPA (1987) questioned the negative conclusion with respect to mice. A second bioassay during which rats were administered 2,000 or 4,000 ppm (50 or 100 mg/kg/day) for 102 weeks did not result in tumor formation (NCI, 1979a). A third bioassay of the metabolite malaoxon also revealed no evidence of oncogenicity (NCI, 1979b).

A recent review by the National Toxicology Program (NTP) reevaluated studies on the carcinogenicity of malathion and its metabolite malaoxon (Huff et al., 1985). The review confirmed the original conclusion of the National Cancer Institute that malathion was not carcinogenic. However, NTP concluded that there was equivocal evidence of carcinogenicity for male and female F344 rats for malaoxon because of C-cell neoplasms of the thyroid gland. Consequently, theoretical lifetime cancer risks were calculated for malathion to estimate the maximum possible risk of cancer. A cancer potency estimate of 0.02 $(mg/kg/day)^{-1}$ was used for the linear model, based on calculations by the California Department of Health Services (1980).

Mutagenicity

Malathion was nonmutagenic in eight microbial assays (American Cyanamid Company, 1986). Malathion was positive in human fibroblast cells in a sister-chromatid exchange assay (American Cyanamid Company, 1986).

In a study conducted by Pednekar et al. (1987), malathion tested negative in six separate assays at levels of 33 and 1,650 mg/L for mutagenic properties using the Ames Salmonella Assay.

Carbaryl

Studies in Humans

Acute and subchronic human exposure to carbaryl has been documented in poisoning reports, worker exposure studies, and volunteer ingestion studies. Ingestion of 2.8 mg/kg of carbaryl (Sevin formulation) resulted in epigastric pain and sweating. These effects were relieved by the administration of the antidote atropine sulfate (Harry, 1977).

Ingestion of carbaryl at dose levels of 0.25, 0.5, 1.0, and 2.0 mg/kg by 10 volunteer subjects resulted in nausea and vomiting in 1 year subject at the highest dose tested, but no toxic effects were observed at the other dose levels (Harry, 1977). Ingestion of a single dose of carbaryl at dosage levels of 0.5, 1.0, and 2.0 mg/kg by two men per dosage level revealed no subjective or objective effects (Wills 1968, as cited in Cranmer 1986).

Oral dosages of 0.6 mg/kg/day and 0.13 mg/kg/day were administered to six men per dosage for 6 weeks in a study conducted by Wills et al. (1968, cited in Cranmer 1986). At the 0.6-mg/kg/day level, no abnormalities in electroencephalogram readings, plasma or erythrocyte cholinesterase levels, clinical hematology evaluations, or urine chemistry were observed. At the 0.13-mg/kg/day level, the only observed effect was a slight yet reversible depression in reabsorption of amino acids in the kidney. This study resulted in a NOEL of 0.06 mg/kg/day (EPA, 1984a).

Dermal application of carbaryl (5 percent Sevin 85W) to 10 human test subjects resulted in depressed erythrocyte cholinesterase levels after 24 hours; however, 5 days after exposure, the cholinesterase levels returned to normal (Harry, 1977).

Whorten et al. (1979, cited in Cranmer 1986) examined semen samples from carbaryl production workers with at least 1 year of carbaryl exposure. The study concluded that there was no obvious depression of the sperm count in the exposed men and no increase in the percentage of abnormal sperm as compared to a control group of men who had not been previously exposed to carbaryl. Subacute dermal and inhalation exposure of carbaryl production workers at 0.44 to 4.9 mg/m^3 did not produce abnormal sperm count or infertility after a 1-year exposure period (EPA, 1984a).

Acute Toxicity

Based on the acute oral LD_{50} for rats of 270 mg/kg, carbaryl can be classified as a moderately toxic insecticide (EPA, 1984a). The acute oral LD_{50} for dogs was reported to be less than 500 mg/kg; for monkeys it was found to be more than 1,000 mg/kg (EPA, 1984a). The acute dermal LD_{50} for

rats was reported to be more than 4,000 mg/kg and more than 5,000 mg/kg for rabbits (EPA, 1984a).

An acute oral cholinesterase LD_{50} rat study reported significant depression of plasma, erythrocyte, and brain cholinesterase in the surviving test animals. A second acute oral cholinesterase study resulted in depression of the erythrocyte cholinesterase level in rats after exposure to carbaryl (in propylene glycol) at a dose of 12.5 mg/kg after 1 and 4 hours (EPA, 1988a). A 7-day rat cholinesterase study reported a NOEL of 10 mg/kg, with decreased levels of erythrocyte cholinesterase at the lowest-observed-adverse-effect level (LOAEL) of 50 mg/kg (U.S) EPA, 1988a).

In addition to evaluations for cholinesterase inhibition, a variety of test species have been tested for transitory neurotoxic effects (weakness, incoordination). The subcutaneous administration of carbaryl to hens at the dose level of 2,000 mg/kg did not induce demyelination (EPA, 1984a).

Subchronic Toxicity

The administration of 150 and 300 mg/kg of carbaryl daily for 8 and 12 weeks did not result in skeletal muscle lesions that could be attributed to delayed neurotoxicity (EPA, 1984a). Upon the histopathological evaluation of tissue sample reports from the above-mentioned studies, EPA concluded that carbaryl does not pose a neurological hazard (EPA, 1984b).

Chronic Toxicity

A 1-year dog feeding study resulted in morphological changes in the kidneys of test animals but no apparent decrease in cholinesterase levels. The cholinesterase NOEL was reported to be greater than 7.2 mg/kg (highest dose tested) (EPA, 1984a). A systemic NOEL of 1.8 mg/kg and a LOAEL of 7.2 mg/kg were reported, based on diffuse cloudy swelling or vacuolization of kidney cells (EPA, 1984a). Similar histological effects have been observed in the kidneys of rats and monkeys after exposure to carbaryl (Wills et al., 1968).

A 2-year rat feeding study reported a systemic NOEL of 200 ppm (10 mg/kg/day). At the highest dose level of 400 ppm (20 mg/kg/day), morphological changes characterized by cloudy swelling were observed within tubules of the kidney and hepatic cords of the liver (EPA, 1984a). No neoplastic changes were observed.

Reproductive and Developmental Toxicity

A study was conducted to evaluate the teratogenic potential of carbaryl administered by gavage or in the diet to mice and rabbits during gestation days 6 to 15 and days 6 to 18, respectively. Dietary administration to mice resulted in no teratogenic effects. A teratogenic NOEL for mice greater than 1,166 mg/kg/day (only dose tested) was reported for dietary exposure, and a teratogenic NOEL greater than 150 mg/kg/day (highest dose tested) was reported for exposure by gavage. Fetotoxic effects in mice, characterized by decreased maternal weight gain and reduced embryo development, were observed at the dietary level of 1,166 mg/kg/day. A maternal NOEL less than 1,166 mg/kg/day was reported, based on decreased weight gain. In the gavage study, decreased weight gain and cholinesterase inhibition were reported as maternal toxic effects. Administration of carbaryl by gavage to rabbits resulted in the

establishment of a teratogenic NOEL of 150 mg/kg/day, based on the occurrence of omphalocele (hernia of the navel). A dose of 200 mg/kg was reported as maternally toxic, and 150 mg/kg was reported as mildly maternally toxic when administered to rabbits by gavage (Murray et al., 1979).

A teratology study using guinea piggs, rabbits, and hamsters resulted in teratogenic effects in guinea pigs but no apparent malformations in hamsters and rabbits. Exposure of hamsters to carbaryl at levels of 125 to 250 mg/kg and rabbits at 50 to 200 mg/kg produced no teratogenic effects. In a study that EPA (1988) considers supplementary, teratogenic bone defects were observed in guinea pigs at the dose level of 300 mg/kg, though another teratology study that exposed guinea pigs to the same dose level produced no teratogenic effects (Weil et al., 1973).

A teratology study that exposed rats to dietary doses of up to 500 mg/kg/day of carbaryl did not result in teratogenic effects. Decreased weight gain was reported as a fetal toxic and as a maternal toxic effect at 500 mg/kg/day (Weil et al., 1972).

A three-generation reproduction study during which rats were exposed daily to carbaryl at 10 mg/kg did not significantly affect fertility, gestation, lactation, or viability of pups (Weil et al., 1972). A second three-generation rat reproduction study established a reproductive NOEL of 200 mg/kg (highest dose tested) when carbaryl was administered as part of the diet (Weil et al., 1973).

A teratology study during which beagle dogs were exposed to 3.125, 6.25, 12.5, 25, and 50 mg/kg of carbaryl throughout the gestation period resulted in a teratogenic NOEL of 3.125 mg/kg. Defects seen at the higher doses included abdominal fissures, failure of skeletal formation, absence of tail formation, and presence of extra toes (Smalley et al., 1968).

The two teratology studies showing positive teratogenic effects in laboratory animals were classified by EPA as supplemental because they did not meet current scientific standards. During the expsoure periods, the number of animals treated was insufficient, the condition of the females was not adequately monitored, and the maternal and fetal blood levels were not adequately monitored in the treatment groups. According to EPA, "the extremely high doses of carbaryl used to elicit effects in the developing organism, coupled with the positive correlation of maternal and fetal toxicity in the multiple species tested (the dog being the possible exception), do not indicate that carbaryl constitutes a potential human teratogenic or reproductive hazard under proper environmental usage" (EPA, 1984b).

Carcinogenicity

Despite speculation that carbaryl could combine with nitrite compounds to form a carcinogen under acidic conditions similar to those in the human stomach, most studies examining carbaryl's carcinogenic potential have been negative. A preliminary report by the Carcinogen Assessment Group concluded that there was no significant increase in the incidence of tumor induction among treated animals relative to control animals (EPA, 1984a). The review of 10 chronic toxicity studies and the absence of significant tumor incidence at 400 ppm in rats and mice has provided sufficient evidence for EPA to conclude "that

carbaryl is not oncogenic in experimental animals" (EPA, 1984b). Results of most of those studies are presented in the following discussion: A 2-year rat oncogenicity feeding study was negative for carcinogenic effects at 400 ppm (20 mg/kg/day) the highest dose tested) (EPA, 1984a). A mouse oncogenicity study during which carbaryl was either given orally at 464 mg/kg for 5 weeks, fed at 14 ppm (2.1 mg/kg/day), or administered under the skin in a single dose of 100 mg/kg did not induce cancer in test animals (EPA, 1984a). Another 2-year mouse oncogenicity study was negative at the dietary level of 400 ppm (60 mg/kg/day) (EPA, 1984a). An intraperitoneal oncogenicity study during which mice were administered carbaryl at a dose level of 60 mg/kg/week produced no oncogenic effects in test animals (EPA, 1984a). The injection under the skin of 10 milligrams of carbaryl per week for a 20-week test period was negative for oncogenic effects (EPA, 1984a). The dermal application of a 57-percent water dilution of carbaryl resulted in no oncogenic effects (EPA, 1984a).

EPA has stated that the following two studies are supplementary: A 22-month rat feeding study at the dose level of 30 mg/kg (highest dose tested) resulted in the induction of malignant tumors in 4 of 12 surviving test animals (EPA, 1984a). Oncogenic effects also were observed after the subcutaneous administration of 20 milligrams of carbaryl to 48 rats; tumors formed in 2 of 10 surviving test animals. However, no significant increase in tumor incidence in treated groups relative to controls was found by the Carcinogen Assessment Group of the Environmental Protection Agency (EPA, 1984a).

N-nitrosocarbaryl Formation

Under acidic conditions similar to those in the human stomach, carbaryl has been nitrosated in the laboratory to the reaction product N-nitrosocarbaryl (Eisenbrand et al., 1975). N-nitrosocarbaryl formation optimally occurs at a pH of 1.0. The pH of the human stomach increases to about 7.0 after a meal and then returns to the normal range of 1 to 2 within minutes (Cranmer, 1986). Very little N-nitrosocarbaryl formation occurs above the pH of 2.0 (Rickard et al., 1982). Elespuru et al. (1974) found that the combination of sodium nitrite (a food additive) with carbaryl in acid solution results in the formatioin of nitrosocarbaryl. It is thought that human exposure to N-nitrosocarbaryl could occur from the reaction of carbaryl residues (in food) with sodium nitrite (in saliva or food) in the acidic conditions of the stomach.

N-nitrosocarbaryl has been characterized as a mutagen and a carcinogen based on positive laboratory studies (Eisenbrand et al., 1976; Elespuru and Lijinsky, 1973). A rat oncogenicity study resulted in the induction of malignant tumors at the injection site in 14 of 16 test animals after exposure to a dose level of N-nitrosocarbaryl at 1,000 mg/kg (Eisenbrand et al., 1975). Rats that were administered N-nitrosocarbaryl by gavage developed a high incidence of stomach tumors (invasive squamous carcinomas) (Lijinsky and Taylor, 1976). A rat feeding study also resulted in the formation of stomach tumors (Lijinsky and Schmahl, 1978).

N-nitrosocarbaryl appears to be a much less effective inducer of mouse skin tumors than other methylating agents such as nitrosomethylurea. Dermal application of N-nitrosocarbaryl (25 microliters of a 0.04-moles-per-liter solution) to the shaved skin of 20 mice led to the induction of skin tumors at the site of application in 8 of the test animals, but only after repeated

dermal applications (twice per week for 50 weeks) to shaved skin. These tumors appeared in 1 of 20 animals at week 60, and in 8 of 20 animals by week 90 (Lijinsky and Winter, 1981). This indicates that N-nitrosocarbaryl could cause cancer in the stomach or on the skin if it could form in the environment as a result of carbaryl applications. However, the literature shows that N-nitrosocarbaryl can form only under conditions similar to those found in the human stomach--not in the air or on the skin. Thus, cancer risk from N-nitrosocarbaryl is considered only for oral exposure to the public.

Mutagenicity

A dominant lethal rat mutation assay indicated that carbaryl was nonmutagenic at the exposure level of 200 mg/kg (highest dose tested) (Epstein et al., 1972). However, chromosomal assays resulted in the induction of mitotic effects and chromosomal aberrations (EPA, 1984a). A bacterial assay characterized N-nitrosocarbaryl as a potent mutagen because of the positive mutagenic response of carbaryl in two bacterial systems (Escherichia coli and Haemophilus influenzae) (Elespuru et al., 1974). The reproductive effects assessment group of the Environmental Protection Agency has concluded that data from mutagenicity studies indicate that carbaryl does not act as a potent mutagen and can be classified as a weak mutagen (EPA, 1984b). EPA has concluded that carbaryl does not pose a mutagenic risk because only weak mutagenic responses have been measured and there is no evidence demonstrating the ability of carbaryl to reach germinal tissue, hence germ cells should not be affected (EPA, 1984b).

Acephate

Acute Toxicity

Based on an acute oral LD_{50} in rats ranging from 866 mg/kg (females) to 945 mg/kg (males), acephate can be classified as a slightly toxic insecticide (EPA, 1984c). An acute delayed neurotoxicity study did not produce leg paralysis in hens exposed to 785 mg/kg/day, which was the only dose tested (EPA, 1984c). The acute dermal LD_{50} for rabbits was reported to be greater than 10,000 mg/kg (EPA, 1984c).

The acute dermal LD_{50} for rabbits exposed to the 75-percent spray formulation of acephate was greater than 10,250 mg/kg (highest dose tested) (EPA, 1984c). An acute inhalation study in rats resulted in an LD_{50} of greater than 61.7 mg/L/4 hour (only dose tested) for the Orthene Specialty Concentrate formulation of acephate (EPA, 1984c).

Acute laboratory testing conducted to evaluate the toxicity of the acephate impurity methylthioacetate (MTA) has demonstrated a potential hazard to the optic tracts and pituitary glands of mammals. An acute dermal study of rabbits exposed to dose levels of 1,500, 2,000, 2,500, and 3,000 mg/kg of methylthioacetate resulted in a nonreversible diminution or absence of the pupillary light reflex and blindness caused by optic tract and pituitary gland damage (EPA, 1985). Additional dermal exposure studies have not resulted in the visual impairment of test animals. EPA has requested further testing to determine the toxic and mutagenic potential of methylthioacetate.

Subchronic Toxicity

A 21-day rat feeding study resulted in a NOEL of less than 30 ppm (1.5 mg/kg/day); 30 ppm was the lowest dose tested and resulted in a 21-percent inhibition of red blood cell cholinesterase during the second test week and a 15-percent inhibition during the third test week (EPA, 1984c). A 21-day dermal rabbit study resulted in a significant decrease in erythrocyte cholinesterase at a dose level of 1.5 g/kg for 25% acephate (EPA, 1984c). A 33- to 34-day oral cholinesterase study during which monkeys were exposed to acephate (2.5 mg/kg body weight) resulted in a 50-percent reduction of plasma, erythrocyte, and brain cholinesterase activities, and a 5- to 17-percent reduction in the activity of cerebrospinal cholinesterase (EPA, 1984c).

Chronic Toxicity

A provisional acceptable daily intake (PADI) level of 0.0025 mg/kg/day has been established for the inhibition of cholinesterase activity, based on the NOEL of 5.0 ppm (0.25 mg/kg/day) derived from a chronic (28-month) rat feeding study and using a safety factor of 100 (EPA, 1985).

A 2-year EPA-validated Industrial Bio-Test dog feeding study established a systemic NOEL greater than 100 ppm (2.5 mg/kg/day), based on the absence of toxic systemic effects; however, a cholinesterase NOEL of 30 ppm (0.75 mg/kg/day) was reported with reduced activities in erythrocyte, plasma, and brain observed at 100 ppm (2.5 mg/kg/day) (EPA, 1984c).

Reproductive and Developmental Toxicity

Teratogenic effects have not been induced in laboratory animals upon maternal exposure to acephate during gestation. A validated Industrial Bio-Test rat teratology study reported a teratogenic NOEL greater than 200 mg/kg (highest dose tested) (EPA, 1984c; EPA, 1987a). A rabbit teratology study also resulted in a teratogenic NOEL greater than the highest dose level tested (10 mg/kg); however, a maternal toxic NOEL of 3 mg/kg was reported, based on increased nasal discharge and increased incidence of spontaneous abortion (EPA, 1984c).

Carcinogenicity

Histopathological examination of tissue specimens from a 28-month rat feeding oncogenicity study revealed no evidence of carcinogenic effects at the highest dose level of 700 ppm (35 mg/kg/day) (EPA, 1987a).

A 2-year oncogenicity study during which mice were exposed to 1,000 ppm (150 mg/kg/day) of acephate resulted in a 15.8-percent incidence of liver tumors (hepatocellular carcinomas) and a 19.7-percent incidence of excessive noncancerous cell growths (hyperplasic nodules) in females. At this dose level, differences in the liver, kidney, brain, and ovary weight values as compared to the control group, and decreased body weight gain also were observed. Liver and lung abnormalities were observed at all testing levels (EPA, 1984c).

The occurrence of liver tumors in female mice has been classified by EPA as limited evidence of carcinogenicity upon evaluation of the following factors: liver tumors occurred only at the highest dose tested (150 mg/kg/day) with no substantial dose-related increase in malignant tumor incidence; no evidence of

tumor metastasis was observed; tumors occurred only in female mice; and tumor incidence was observed only at the end of the study. In accordance with EPA guidelines for carcinogenic risk assessment (Federal Register, Section 1(185); 33992-34003, September 24, 1986), EPA has concluded from this evidence that acephate is a weak carcinogen. Therefore, with the use of protective clothing and required label specifications, EPA believes that no unreasonable adverse effects will occur from using products containing acephate (EPA, 1985). However, a theoretical cancer risk assessment is presented in section 4.

Mutagenicity

Acephate was positive when tested in an unscheduled DNA systhesis assay in human fibroblast cells, mitotic crossing-over and gene conversion assays in yeast cells, the CHO (Chinese hamster ovary) cell cytotoxicity assay, bacterial recombination assays, bacterial reverse gene mutation assays, bacterial mitotic crossing-over assays, bacterial gene conversion assays, gene mutation assays in mammalian cells, and the sister chromatid exchange assay in CHO cells (EPA, 1984c). Weakly positive results were reported on the exposure of acephate to bacterial mutagenicity assays and the bacterial Ames assay (EPA, 1984c). Negative results were reported for the *in vivo* mouse micronucleus assay, the bacterial Ames assay, the dominant lethal mouse in vivo assay, the in vivo cytogenetic mouse bone marrow cell assay, sister chromatid exchange, and chromosomal aberration assays of monkeys and mice (EPA, 1984c). Both weakly positive and negative results were reported for a second unscheduled DNA systhesis assay in human fibroblast cells (EPA, 1984c).

According to EPA (1985), "The overall conclusion is that acephate has a definitive effect in a number of mutagenic assays. The in vivo assays, which were without response, are generally regarded to be of lesser activity; nonetheless, these negative effects show that acephate is not a strong mutagenic agent under in vivo conditions, while moderately mutagenic in cellular systems (prokariots [sic] and eukariots [sic])." This risk assessment assumes acephate is a weak mutagen with a risk of mutations no greater than that computed for cancer.

Methamidophos

Acephate is metabolized in mammalian systems to methamidophos, a relatively more toxic compound that is a registered insecticide itself. As much as 10 to 29 percent of applied acephate is transformed to methamidophos in other animals, plants, and environmental media (see Appendix A).

Studies in Humans

The lowest toxic dose of methamidophos reported for humans is 257 mg/kg (RTECS, 1987). Toxic signs were observed in the peripheral nervous system, eyes, and skin. Effects similar to those reported for other organophosphates would be expected, particularly those that are associated with ChE inhibition.

Humans ingesting 256 mg/day for 5 days or 64 mg/day for 4 weeks exhibited no symptoms or detectable effects on plasma and red blood cell ChE activity (NLM, 1987a). In a 73-day study in humans, a NOEL of 0.1 mg/kg/day was reported based on ChE inhibition in red blood cells after ingestion of a 1 to 4 mixture of methamidophos to acephate. For a 1 to 9 mixture of methamidophos to

acephate, a NOEL of 0.2 mg/kg/day was determined (EPA, 1982a). The dose of methamidophos would be 0.02 mg/kg/day for either NOEL (1/5 of 0.1 mg/kg/day or 1/10 of 0.2 mg/kg/day).

NOEL and ADI levels were not established by EPA (1982b) because of data gaps. The Food and Drug Administration (1980) reported an ADI by FAO/WHO of 0.002 mg/kg/day.

Acute Toxicity

Based on acute oral LD_{50} values of 13 to 15.6 mg/kg in rats, methamidophos is classified as very toxic by EPA (1982a). A lower oral LD_{50} of 7.5 mg/kg for rats was reported in the Registry of Toxic Effects of Chemical Substances (RTECS 1987). As illustrated in table 2-5, which gives LD_{50} values for various mammals, methamidophos is 10 to 70 times more acutely toxic than acephate.

Methamidophos was very toxic when applied dermally to rabbits, based on an LD_{50} of 118 mg/kg (EPA, 1982a). Although methamidophos is considered a mild to moderate skin irritant, it was readily absorbed through the skin and was lethal to 55 to 67 percent of the rabbits studied.

Subchronic Toxicity

In a 90-day dog feeding study, a systemic NOEL of 0.375 mg/kg/day was established (EPA, 1982a). The lowest effect level was 0.125 mg/kg/day, based on plasma and erythrocyte acetylcholinesterase inhibition.

Chronic Toxicity

Two-year chronic feeding studies reported no significant effects in dogs fed 0.75 mg/kg/day and in rats fed 10 mg/kg/day (NLM, 1987a).

Results of a recently reviewed 1-year dog study and a 2-year rat study show that brain cholinesterase inhibition, the effect of concern in these studies, was observed at the lowest dose tested, which was 2 ppm (0.05 mg/kg/day) in both studies.

Reproductive and Developmental Effects

Methamidophos was not embryotoxic or teratogenic to rabbits at 2.5 mg/kg, the highest dose tested (EPA, 1982a). However, maternally toxic effects were observed at all levels (0.1, 0.5, and 2.5 mg/kg), based on decreased weight gain.

Carcinogenicity

Methamidophos was not oncogenic in a rat-feeding study at 3, 10, and 30 ppm (FDA, 1980). Results of two additional studies indicate that methamidophos was not oncogenic in rats at dose levels of 2, 6, 18 and 54 ppm or in mice at dose levels of 1.5, and 25 ppm (EPA, 1976).

Mutagenicity

In a dominant lethal assay with mice, intraperitoneal injection of 1 and 2 mg/kg did not result in mutagenic effects. Results of *in vitro* studies with several strains of bacteria were also negative (FDA, 1980). Additional mutagenicity testing is required according to EPA (1987b).

Bacillus thuringiensis

The toxicological effects of *Bacillus thuringiensis* (*B.t.*) formulations are caused by several biologically active metabolic products of the bacterium. The delta-endotoxin is the basis for most commercial formulations. The insecticidal activity of the delta-endotoxin in the gut of insects occurs when the parasporal crystalline material is degraded under alkaline conditions. Two metabolic products of *B.t.*, which are known to be toxic to invertebrates and vertebrates, are the beta-exotoxin and the alpha-exotoxin. Formulations of *B.t.* that are currently used for Forest Service applications include Dipel and Thuricide, which do not contain either of these metabolites. Beta-exotoxin is not synthesized by the strain (var. kurstaki) from which Forest Service formulations are derived. Although the alpha-exotoxin is denatured during the manufacturing process, there is a potential for its production by vegetative bacterial cells in infected insects (Luthy, 1980, cited in Sassaman, 1987).

Most *B.t.* toxicity studies do not specify the toxin that was actually associated with the observed effect, nor do they specify that the observed effect was caused solely by the delta-endotoxin without interference from other toxins produced by *B.t.* Limited data are available on the specific toxicological effects of the delta-endotoxin on nontarget organisms. Data presented in the hazard analysis are primarily concerned with the potential toxic effects of the delta-endotoxin. Toxicity studies using *B.t.* that do not specify the toxic agent (i.e., specific toxin) are identified as such.

The available literature is varied with regard to the units of measurement used to quantify toxicity. Toxicity studies that are presented in this text employed the following units of measure: number of viable spores per unit weight or unit volume, unit weight or unit volume applied per unit area, and percent active ingredient formulation.

Because of the nonspecific details of many *B.t.* toxicity studies available in the literature, in particular with regard to mammalian toxicity, it is difficult to evaluate the toxicity of *B.t.* by the standards used for other insecticides. *B.t.* formulations currently used by the Forest Service are generally nontoxic to mammals, including humans, because these formulations do not contain the alpha-exotoxin or the beta-exotoxin. Studies with *B.t.* formulations that do not contain alpha- or beta-exotoxin revealed no acute, subchronic, or chronic toxicity.

Human Health Effects

In one exposure incident, an 18-year-old farmer suffered eye irritation after accidentally splashing a suspension of Dipel in his right eye (Samples and Buettner, 1983, as cited in Sassaman, 1987). The eye was immediately irrigated with water and treated with an unspecified antibiotic ointment. The eye remained irritated and was treated with corticosteroid ointment (an anti-inflammation agent) 3 days after exposure. An ulcer in the cornea was noted 10 days after the accident. *B.t.* was isolated from the lesion, which

healed after 2 weeks of topical treatment with the anti-biotic Gentamicin and 1% atropine. Sandoz, the manufacturer of Dipel, responded to this incident by pointing out that the application of corticosteroid confounds the etologic link with B.t. and questions the pathogenicity of the Bacillus. Their laboratory studies of direct application of B.t. to the eye resulted in no evidence of pathogenicity to the eye under properly controlled studies. In addition, production workers have made no complaints.

Fisher and Rosner (1959, as cited in Sassaman, 1987) reported the lack of chronic toxicity among workers exposed to B.t. during various stages of the production of pesticidal formulations. The individuals were exposed to whole fermentation broth, moist bacterial cake, effluent, and final powder (10 grams to several thousand pounds per day containing up to 15×10^9 viable spores per gram). The workers were free of any complaints during the 7 months of observation. Two individuals underwent comprehensive medical examinations and showed no evidence of acute or chronic toxicity. The specific formulations of B.t. were not specified in this report.

Acute Toxicity

No deaths were reported among mice when B.t. was administered orally at 0.3 and 1.5×10^6 spores per gram (Kimura 1970, as cited in Sassaman, 1987). The toxin in this formulation was not specified. Hernandez and Mclean (undated, as cited in Sassaman, 1987) administered B.t. spores to rats in the feed for 1 day. No deaths, adverse effects on body weight gain, or abnormalities in blood counts were observed among the treated animals during a 13-day observation period. The test material in this study may have contained beta-exotoxin as a toxic agent.

No irritation was observed 3 days after a 20-percent suspension of Dipel was applied to either shaved unabraded or shaved abraded skin of the rabbits (Kimura, 1980 as cited in Sassaman, 1987). Skin irritation was observed in the form of erythema and eventual dry skin and sloughing, leaving a smooth, hairless treatment area following application of Dipel 4L to the skin of rabbits at 7.2 g/kg in an acute dermal toxicity study (Abbott, 1986, cited in Sassaman, 1987).

No mortalities were observed among an unspecified number of mice or rats 7 days after they were exposed to an aerosol of a 20-percent suspension of Dipel for 10 minutes (Kimura, as 1970, cited in Sassaman, 1987).

No acute eye irritation was observed in rabbits following ocular instillation of 0.1 ml of a 10-percent suspension of Dipel (Kimura, 1970, as cited in Sassaman, 1987).

Subchronic Toxicity

In a 13-week Dipel feeding study conducted by Olson and Kwapien (1973, as cited in Sassaman, 1987), 10 rats per group were administered 0.84 mg/kg for 1 week, then 8.4 mg/kg for 12 weeks (group 1); and 8.4 mg/kg for 1 week, then 8,400 mg/kg for 12 weeks (Group 2). A third group served as the untreated control group. No significant findings were observed in hematology, clinical chemistry, or urinalysis evaluations. In addition, there were no abnormal findings in the gross pathology or histopathology evaluations.

Biotrol was administered in the diet to groups of 20 rats at dietary levels of 1, 1.25, 5, and 10 percent for 49 days (Forsberg et al., 1976, as cited in Sassaman, 1987). No significant differences were observed between treated and control groups of animals.

Chronic Toxicity

Administration of Biotrol (25 x 10^9 spores per gram) at a 1 percent level in the diet of 25 female and 25 male rats for 2 years revealed no significant differences between control and treated groups of animals (Barnes, 1970, as cited in Sassaman, 1987).

Reproductive and Developmental Toxicity

The literature contains no data about the reproductive or teratogenic effects of B.t.

Carcinogenicity

The literature contains no data about the carcinogenic potential of B.t.

Mutagenicity

Growing root stems of *Allium cepa*, *A. savivum*, and *Vicia faba* were exposed to delta-endotoxin protein. All test materials were negative in all systems (Panda et al., 1979, as cited in Sassaman, 1987).

Diesel Oil

Acute Toxicity

Sevin 4-Oil is formulated with petroleum products and diluted with diesel oil. Beck et al. (1982) conducted a short-term exposure study examining the acute toxicology of 19 petroleum hydrocarbons in acute oral, acute dermal, subacute dermal, and eye irritation studies. Based on an acute oral LD_{50} of 9 mL/kg (7,380 mg/kg), diesel oil can be classified as a very slightly toxic compound. The most marked acute toxic effect observed after the administration of diesel oil to test animals occurred during primary dermal irritation studies. A single dermal diesel oil exposure to rabbits resulted in a rating of "extremely irritating" based on a score of 6.82 (on a scale of 1 to 10), although the irritation may have been caused by additives to the diesel oil for use in internal combustion engines. Diesel oil was nonirritating in primary eye irritation studies.

Subacute Toxicity

A subacute 3-week dermal study of eight rabbits resulted in an average weight loss of 0.38 kg at the dose level of 4 mL/kg (3,280 mg/kg), and an average weight loss of 0.55 kg with a 67-percent mortality rate at the dose level of 8 mL/kg (6,560 mg/kg).

Reproductive and Developmental Toxicity

An inhalation teratology study in which rats were exposed to 101.8 ppm or 401.5 ppm (5.09 or 20.075 uL/kg) of diesel fuel on days 6 through 15 of gestation did not result in any significant teratogenic effects (Mecler and Beliles, 1979).

Carcinogenicity of Petroleum Distillates

The carcinogenic potential of petroleum fuels is directly related to refinery processing methods used to obtain the petroleum product and the crude oil composition from which the fuel was derived. An evaluation of the composition of petroleum fuels has revealed that a positive correlation exists between polycyclic aromatic hydrocarbon (PAH) content and carcinogenicity in human epidemiology studies or experimental laboratory studies (Bingham et al., 1979).

Diesel oil is a complex variable mixture of hydrocarbons with a boiling point range of 170 to 370 $^{\circ}$C and an aromatic content ranging up to 35 percent (DOE, 1983). Diesel fuel is usually a straight-run distillation product that boils below 650 $^{\circ}$F and contains few polycyclic aromatics, has not been shown to be carcinogenic. Kerosene is a straight-run petroleum distillation fraction (NLM, 1987b), with a boiling point range of 175 to 325 $^{\circ}$C and an aromatic content of 15 to 20 percent.

A 2-year oncogenic skin painting study, which was terminated after 62 weeks, during which Swiss Epley mice were exposed to 0.05 mL (41 mg) of diesel fuel products resulted in skin carcinomas in 2 of 50 animals, which was not statistically significant by chi-square analysis. The study was prematurely terminated because of the presence of extensive skin lesions in test animals (American Petroleum Institute, 1983a). Higher boiling point (greater than 700 $^{\circ}$F) petroleum products subjected to additional refinement processes, such as cracking or hydrogenation, and that contain polycyclic aromatics may be carcinogenic to experimental animals (Bingham et al., 1979).

Specific substances that are known or suspected of being carcinogenic, which are contained in diesel oil and kerosene in small amounts include benzo(a)pyrene and benzene. Benzo(a)pyrene (BaP), a potent carcinogen, is a PAH that also occurs at low levels in foods and in products of combustion, including cigarette smoke. Bioassays have indicated that the concentration of this single carcinogen can often serve as a guide in predicting carcinogenic potency of petroleum distillates, although other substances are also known to be involved (Bingham et al., 1979). Sufficient evidence exists for the carcinogenicity of BaP in experimental animals: BaP has produced tumors in all of the nine species for which data have been reported following various methods of administration (DHHS, 1985); it has both a local and systemic carcinogenic effect. EPA has estimated the carcinogenic potency of BaP as 11.5 $(mg/kg/day)^{-1}$ (EPA, 1986b).

For benzene, another aromatic known to be present in diesel oil and kerosene, sufficient evidence exists for its carcinogenicity in experimental animals (DHHS, 1985). It also has been shown to cause leukemia in workers with chronic exposure.

EPA has estimated the carcinogenic potency of benzene as 0.0445 $(mg/kg/day)^{-1}$ (EPA, 1986c). But benzene can occur at greater concentrations (approximately 29 ppm in No. 2 fuel oil) than BaP in diesel oil. Consequently, the

carcinogenic potencies of diesel oil have been estimated for this EIS based on the potencies of both benzene and BaP.

Samples of diesel oil and fuel oil have been found to have a BaP content of only 26 ppb, but No. 2 heating oil (which may be subjected to cracking, rather than straight-run distillation) can contain 600 ppb (Bingham et al., 1979). The midpoint of this concentration range (313 ppb) has been used to calculate the carcinogenic potency of diesel oil, although most diesel fuels can be expected to have a lower BaP content. The content of benzene in diesel fuel was assumed to be 28.5 ppm, based on analysis of water extracts of No. 2 fuel oil by Anderson (1975), with corrections for solubility relationships. The resulting estimate of carcinogenic potency of diesel oil is 4.9×10^{-6} $(mg/kg/day)^{-1}$. Seventy-four percent of this potency is a result of the BaP component.

A case control epidemiology study revealed an increased relative risk of developing bladder carcinoma in men who are occupationally exposed to oil or gasoline, kerosene, chemical materials, or asphalt (Mommsen and Aagard, 1984).

Petroleum products with boiling points greater than those of kerosene or diesel fuel (greater than 370^{o} C) that are subjected to additional refinement processes, such as cracking or hydrogenation, and that contain polycyclic aromatics may be carcinogenic to experimental animals (Bingham et al., 1979).

Mutagenicity

Diesel fuel was nonmutagenic when tested in the Ames assay and the mouse lymphoma assay; however, it was found to be clastogenic (causing chromosomal aberrations) in rat bone marrow cells (Conaway et al., 1982). Because diesel oil contains polycyclic aromatic hydrocarbons and other constituents that are known or suspected mutagens, it is considered to be a mutagen for this risk assessment.

<u>Kerosene</u>

Acute Toxicity

Kerosene can be classified as very slightly toxic, based on the lowest oral lethal dose of 28,000 mg/kg in rats (NLM, 1986). Toxic effects after ingestion include irritation of the mouth, throat, and stomach; nausea and vomiting; drowsiness; rapid heart beating; and shallow respiration (ITII, 1976). In primary irritation studies, jet fuel A (a type of kerosene with a boiling range of 163^{o}C to 282^{o}C) was mildly irritating to the skin and eyes of rabbits and was nonsensitizing to guinea pigs (Beck et al., 1982). Jet fuel A caused no mortalities in rats given acute dermal doses of 5,000 mg/kg (Beck et al., 1982).

The lowest intratracheal lethal dose of kerosene in rats is 800 mg/kg (NLM, 1987b). Inhalation of kerosene may cause headaches, excitement, dizziness, languor, ataxia (defective control of muscles), nausea, bronchitis, anemia, and inflammation of the nerves (ITII, 1976). Intratracheal instillation of kerosene into rats caused an increase in lung weight in proportion to body weight, suggesting pulmonary congestion (Scharf et al., 1981). Scharf and colleagues also observed hyperemia (much greater than normal blood flow) of the

lungs, focal bronchopneumonia, and increased total lung capacity. These changes were maximal by 24 hours after instillation and returned to normal within 2 weeks.

Results of a study in which kerosene was administered to baboons by various routes suggest that the primate brain is resistant to the direct toxic effects of kerosene (Wolfsdorf and Paed, 1976). The authors concluded that even at high dose levels, the liver and lung were able to filter out sufficient amounts of kerosene to protect the brain from damage.

Subchronic Toxicity

In a 28-day dermal toxicity study with hydrodesulfurized kerosene, rabbits showed dry, flaking and/or cracking skin, scab formation, necrosis (localized cell death), sloughing, fissuring, thickened skin, and ulcerations at all dose levels (200, 1,000, and 2,000 mg/kg/day) (American Petroleum Institute, 1983b). At the high-dose level (2,000 mg/kg/day) rabbits exhibited treatment-related skin and liver lesions.

In a 3-week dermal toxicity study with jet fuel A, exposure to 8.0 mL/kg/day caused 75 percent mortality of rabbits (Beck et al., 1982). Treatment-related effects included anorexia, weight loss, depression, severe dermal irritation, and pale liver and kidneys.

Male rats were given subcutaneous administration of commercial kerosene at 0.5 ml/kg/day, 6 days per week for 5 weeks (Rao et al., 1984). Treatment-related effects included increased weight of the liver, spleen, and peripheral lymph nodes; increased DNA, RNA, protein, and lipid contents of the liver and spleen; lesions in the liver, spleen, thymus, kidney, adrenal, and lymph nodes; and imbalanced enzyme levels (decreased activity of succinate dehydrogenase, glucoso-6-phosphatase, magnesium-stimulated adenosinotriphosphatase and increased activity of acid phosphatase).

Rats exposed to 75 and 300 mg/m^3 of kerosene mist for 14 weeks exhibited functional, morphological, and cytoenzymatic changes in the lungs and kidneys (Starek and Kaminski, 1981 and 1982). Changes in the kidney were associated with the magnitude of exposure (Starek and Kaminski, 1982), and disturbances of the acid-base equilibrium in blood were noted (Starek and Kaminski, 1981).

Carcinogenicity

The carcinogenic potential of kerosene is similar to that of diesel oil since the same substances (BaP and benezene) are responsible in both cases. The discussion of kerosene's carcinogenicity is included in that of diesel oil's.

Mutagenicity

Kerosene was nonmutagenic both with and without metabolic activation in the Ames bacterial assay and the mouse lymphoma assay (Conaway et al., 1982). Kerosene also was nonmutagenic in the rat cytogenetic bone marrow assay (Conaway et al., 1982).

ECOLOGICAL HAZARDS

Malathion

Mammalian Toxicity

Malathion is moderately toxic to mammals. The lowest oral LD_{50} for rats is 370 mg/kg.

No effects on wildlife were observed in population censuses, carcass counts, and tissue residue analysis in areas sprayed at 6.8 oz a.i./acre of malathion (McEwen et al., 1972 as cited in Dobroski and Lambert, 1984).

The discussion in the human health hazard subsection of this risk assessment provides details on the chronic toxicity, oncogenicity, teratogenicity, and mutagenicity of malathion.

Avian Toxicity

The oral LD_{50} of malathion to chickens is 150 mg/kg to 850 mg/kg (EPA, 1975). The oral LD_{50} is 167 mg/kg for pheasants and 403 mg/kg for the horned lark (Hudson et al., 1984). The LD_{50} in mallards is 1,485 mg/kg.

Signs of intoxication that appeared at lethal and near-lethal doses included ataxia, walking high on toes, imbalance, hypoactivity, wind-drop, weakness, slowness, sitting, ptosis, falling with wings spread, tenesmus, salivation, swallowing, tremors, dyspnea, and convulsions (Hudson et al., 1984).

A study in Michigan found no significant adverse effects on birds and mammals in areas sprayed with malathion at 1 lb a.i./acre. Caged pheasants held in the area showed no adverse effects and no effects were observed in necropsied birds (DOI, 1963). In Texas, cotton fields were repeatedly treated with malathion at 12 oz to 16 oz a.i./acre. No effects on birds were noted in wildlife areas adjacent to the fields. Caged quail held among treated rows of cotton also showed no effects (Sinclair, 1968).

Areas in Nebraska treated with 8 oz a.i./acre of malathion showed no significant effects on birds or mammals. However, domestic turkeys that were held in cages in treated areas and allowed to feed on insects from the treated area had slightly depressed plasma ChE levels, but no external symptoms were noted (USDA, 1985).

Birds in a forested watershed that had been treated with 0.7 lb a.i./acre of malathion appeared noticeably quiet for a 2-day period after the spraying. This may have been the result of acetylcholinesterase inhibition, which has been directly related to a decrease in physical activity. No other effects were observed (Dobroski and Lambert, 1984).

Malathion at extremely high doses has been shown to decrease brain AChE in quail and mallards (Dobroski and Lambert, 1984). Although malathion appears to reduce brain ChE and AChE levels, the minimum application rate to cause this effect has not yet been determined. Further research in this area has been suggested by the U.S. Fish and Wildlife Service (1986).

In a study that measured brain cholinesterase activity after a city-wide aerial application, malathion was shown to reduce ChE of sparrows from 6 to 12 percent

as compared to their respective activity levels before the treatment. The application rate for this study was 140 mL/hectare (Kucera, 1987).

Effects on Avian Reproduction. Reproductive effects of malathion have been studied in chickens. Birds were exposed to increasing amounts of malathion in their feed for 29 weeks. Doses were 100 mg/lb of feed for 4 weeks, 200 mg/lb of feed for 3 weeks, and 500 mg/lb of feed for 22 weeks. Test results indicated reduced weight gains and a 25-percent mortality of test birds. Egg production was not affected (EPA, 1975). In study with chickens, no reduction in hatchability of eggs was observed after 2 years of exposure to 2,500 ppm of malathion in feed (EPA, 1975). In study, eggs injected with 2.5 mg each of malathion and carbaryl did not hatch (Ghassemi et al., 1981). Other studies have confirmed the reduced hatchability of chicken eggs after malathion injection (NRC, 1977).

Insect Toxicity

Effects on Honey Bees. Malathion is highly toxic to bees and can cause severe losses if bees are present at the time of treatment with this pesticide. Damage to bee populations can be considerably reduced by timing the application to avoid exposing bees to freshly applied malathion. The 48-hour LD_{50} in honey bees (*Apis mellifera* L.) is 0.709 ug per bee for exposure to malathion dust (Atkins et al., 1973).

Treatments while bees are foraging in the field are usually the most hazardous. Furthermore, application over colonies in hot weather when bees are clustering on the outside of the hives may result in severe losses. Treatments during night and early morning before bees begin foraging are safest. Usually, injury is not significant to colonies one-quarter of a mile or more from treatments unless the treated field is the only attractive crop in the area. The farther the colonies are from the treatment area, the less critical the treatment time. Colonies moved into the field 2 or 3 days after treatment usually escape damage (Dobroski and Lambert, 1984).

Residual action of ultra-low-volume (undiluted) application of malathion on bees exhibits four times greater toxicity than that usually encountered after dilute applications. Pesticide applications by aircraft have been shown to be more hazardous than application by ground equipment. Granular application has been shown to be the safest method of treatment for bees (Dobroski and Lambert, 1984).

Bees collecting pollen from treated areas may be killed in great numbers when walking over treated surfaces, but an equally significant danger lies with the pollen itself. Older bees (normally the worker bees) are less susceptible to malathion and may carry contaminated pollen back to the hive before they sicken and die. Young and reproductive members of the colony that eat the pollen also may die. Once in the hive, the contaminated pollen may remain toxic for months. However, if bees are removed beyond flight range from an area to be sprayed and not returned for 3 days, mortality is not significant. Most recommendations include moving the colony for a brief period or confining the bees to their hive before and shortly after spraying (Dobroski and Lambert, 1984).

Effects on Other Beneficial Insects. As a broad spectrum pesticide, there is little, if any, selectivity between the toxicity of malathion to target pests and to beneficial insects on the same plant (Dobroski and Lambert, 1984).

Malathion is toxic to beneficial parasites and predators such as ladybird beetles and parasitic wasps. A study of beneficial insect populations was conducted over 4 years where repeated applications of 12 and 16 ounces of active ingredient malathion were made annually. The applications resulted in an adverse effect on ladybird beetles, scymnus beetles, hooded beetles, softwinged flower beetles, and lace-winged beetles immediately after the application. However, the researchers found no major differences in the spring populations of beneficial insects (Huddleston et al., 1968).

Investigations of malathion application suggest that certain insect orders are more susceptible than others. Observations of the effects of low-volume aerial application of malathion for mosquito control showed that the insect orders Homoptera (cicadas, leafhoppers, and the like) and Hemiptera (the true bugs) declined during the treatment period, whereas other insect orders, including Diptera (the flies), with the exception of family Culicidae (the mosquitoes), were not affected. Many insects in the order Hymenoptera (bees, wasps, ants, and the like) seemed to be especially susceptible to malathion (Dobroski and Lambert, 1984).

Another study of the effects of malathion applications (8 oz a.i) to nontarget leafhoppers indicated only one of five monitored species failed to recover to control area population levels within 2 weeks after treatment. One species, Scaphytopius acutus (Say), was suppressed from one growing season to the next.

Reductions in beneficial predator wasps and parasites are only temporary because of the short-lived residues of malathion (Manser and Bennet, 1963).

Aquatic Species Toxicity

The acute toxicity of malathion for a number of aquatic organisms is shown in table 2-6.

Fish. Fish sensitivity to malathion depends on species, water quality, temperature, and exposure times (EPA, 1975). In general, malathion appears to have a moderate level of toxicity to some species of fish. Species such as carp may tolerate this insecticide at the normal rate of application in mosquito control, whereas others, such as striped bass and mosquito fish, may suffer moderate to high mortality.

Malathion applied for grasshopper control in Montana slightly reduced brain cholinesterase levels between prespray and postspray samples of cutthroat and eastern brook trout. No effect was observed on the live caged fish as a result of the 8-ounce malathion application (DOI, 1967).

Two farm ponds repeatedly treated with 16 ounces (1.16 pounds) per acre of malathion were studied in a cotton-growing area of Texas. No mortality was reported for resident largemouth bass and other game fish and forage species (Fischer, 1966).

Results from an investigation of the direct effects of a wide area application of malathion on fish indicated that, when aerially applied at the ultra-low-volume rate, malathion did not result in direct mortality of captive bluegill (Lepomis macrochirus) and fin fish populations native to the stream running through the study area (Dobroski and Lambert, 1984).

An investigation of the relative susceptibility to insecticides of representatives in the families Ictaluridae (catfish), Cyprinidae (minnows), Centrarchidae (sunfish and bass), Percidae (perch), and Salmonidae (salmon, trout, and chars) demonstrated that members of the families Ictaluridae and Cyprinidae were considerably more tolerant of malathion than species in the other families studied.

Aquatic Invertebrates. The most acutely sensitive aquatic invertebrates to malathion are scuds (amphipods), stoneflies, and caddisflies (see laboratory test results in table 2-6). Field studies support the finding that scuds are sensitive to malathion. Study sites in Wyoming treated with 8 ounces of malathion per acre indicated that the amphipod Hyalella azteca (saussure) was reduced to nearly zero and showed no recovery 1 year later (Pfadt et al., 1985).

However, some studies have shown differences between laboratory and field effects on aquatic arthropods. Shrimp and Daphnia have been shown to be very sensitive to malathion in the laboratory, but ground applications at typical mosquito control levels resulted in no significant effects on crustacea, including shrimp and plankton species (Dobroski and Lambert, 1984).

Malathion was not found to be toxic to red crawfish at concentrations that were effective in large-scale control of the target pests (Muncy and Oliver, 1963).

Aerial applications of malathion have been implicated in population reductions of the insect families Chironomidae (midges), Ceratopogonidae (biting midges), Sciaridae (gnats), and Empidae (dance flies) and the orders Collembola (springtails), Plecoptera (stoneflies), and Ephemeroptera (mayflies). However, reductions of aquatic populations appear to be short lived, and rapid recovery is likely (Dobroski and Lambert, 1984).

Aquatic Plants. No adverse effects of malathion on aquatic plants have been reported. Algae metabolize malathion quite rapidly, and the degradation products are not harmful (Mulla and Mian, 1981). Field studies of ULV aerosol applications of malathion to a salt marsh resulted in no adverse effects to aquatic plants (Tagatz et al., 1974).

Carbaryl

Mammalian Toxicity

Carbaryl is considered moderately toxic to mammals. The acute oral LD_{50} of carbaryl ranges from 150 mg/kg to 710 mg/kg for mammalian species (Ghassemi et al., 1981; Hudson et al., 1984; NLM, 1986b). Carbaryl is used on cattle and pets to control insect pests. Acute oral LD_{50}'s for mammals and birds are shown in table 2-7.

Several studies have examined the effects of carbaryl on wild populations of small mammals with varying results, according to application rates. The proposed rate for this program is 0.5 lb a.i./acre (8 oz a.i./acre) of carbaryl, which is lower than any of the reported studies. In Canada, no changes were observed in small mammal populations 2 months after spraying forested areas with carbaryl for spruce budworm control (Buckner et al., 1973). A study of an area in New York treated with 1.25 lb a.i./acre of carbaryl reported no adverse effects on small mammals or deer (Connor, 1960).

Denisova (1973) reported a decrease in mole and rodent populations in forests treated with carbaryl at a high rate (4.46 lb per acre). No recovery of populations was reported within 2 years. Tissue residues of carbaryl in males were 5 mg/kg in reproductive organs, 3 mg/kg in liver, and 1.5 mg/kg in muscle.

Barrett (1968) reported a decline in cotton rat populations, an increase in house mouse populations, and no change in old field mouse populations following treatment of a millet field at 2 lb a.i./acre of carbaryl. Carbaryl residues in millet were 35 ppm. There was a 4-week delay in the reproductive cycle of the cotton rat. Laboratory studies by Barrett supported these findings. Doses of 1.1 mg/adult/day (similar to those in the field study) resulted in a greater than 50-percent decline in the number of female cotton rats giving birth and in the total number of litters. At the same dose, reproduction in the house mouse was not affected.

Avian Toxicity

Carbaryl is considered slightly toxic to birds. It is used on poultry to control insect pests. The acute oral LD_{50} ranges from 780 mg/kg to more than 2,500 mg/kg for avian species (Ghassemi et al., 1981; Hudson et al., 1984; NLM, 1986b). The LD_{50} is greater than 2,564 mg/kg for mallards. Toxic symptoms observed in birds at lethal or near-lethal doses include inactivity, ataxia, regurgitation, weakness, fluffed feathers, salivation, slowness, lethargy, tachypnea, tremors, ataraxia, tetany, paralysis, coma, and convulsions (Hudson et al., 1984).

Results of carbaryl studies on birds vary. A number of studies have reported no effects on bird populations in areas treated with carbaryl. Several studies have reported decreased levels of ChE activity. One study has reported significant declines in bird populations possibly resulting from reduced food supplies.

The following studies showed no adverse effects at application rates at least two times that of the rate proposed for the Forest Service's spruce budworm control program (0.5 lb a.i./acre): In New York, an area was treated with carbaryl at a rate of 1.25 lb a.i./acre. No effects were observed on behavior, reproduction, or rearing of young in 49 species of birds (Connor, 1960). Following carbaryl spraying, no significant effects were observed on nesting success, total number of breeding birds, mortality rates, or brain ChE levels (Zinkl et al., 1977). Richmond et al. (1979) reported a similar lack of adverse effects to birds in Oregon after applications of 2 lb a.i./acre of carbaryl. No adverse effects were reported in birds in Colorado at a rate of 1 lb a.i./acre (McEwen et al., 1962). Bart (1979) reported no changes in bird populations or song frequency in forest plots treated at 1 lb and 5 lb of carbaryl per acre. No changes in songbird populations occurred up to 3 weeks

after spraying Canadian spruce forests at 1 lb carbaryl per acre (Buckner et al., 1973).

A decrease of brain cholinesterase in forest birds in Montana was measured after applications of carbaryl at 1 lb a.i./acre (Zinkl et al., 1977). The authors suggested that ChE depression to the levels observed may reduce a bird's ability to avoid predators and to obtain food. Another study reported no decrease in ChE levels in birds in Maine forests treated at 0.31 lb and 0.69 lb per acre (Gramlich, 1979). Knowledge is lacking regarding the minimum application rate of carbaryl that causes ChE depression. Further research is needed in this area to more accurately assess impacts on wildlife.

Forested areas in New Jersey treated in June for gypsy moth control with carbaryl at 1 lb/acre resulted in a 55-percent decrease in bird populations within 2 weeks after spraying and showed no recovery during 6 more weeks of monitoring or in the following year during June and July (Moulding, 1972). The unsprayed plot showed no significant changes. It was noted that canopy species were more affected than ground feeders. The author suggested the following possible explanations for the overall decline of birds: opportunistic feeding outside the sprayed area, possible reduced reproductive success, or a shift in nest-site loyalty, all of which may be a result of reduced insect populations and food supply. Doane and Schaefer (1971) have suggested that the removal of gypsy moth larvae, which is an important food source for birds, could cause migration of birds out of treated areas.

Effects on Avian Reproduction. Studies indicate the possibility that extensive use of carbaryl may cause a significant reduction in reproductive success of avian species, especially quail and pheasant. DeRosa et al. (1976 as cited in EPA, undated) found residues of carbryl in yolks of Coturnix quail eggs produced 8.5 hours after treatment levels similar to those encountered in the field. Fecal analysis indicated that carbaryl residues were no longer present at 52 hours. Exposure to a second treatment caused significant reduction in egg production in direct proportion to treatment levels. Egg viability was not affected; however, agonistic behavior was decreased in males but increased in females after pesticide ingestion. DeRosa et al. suggested that these behavioral modifications may disrupt pair formation in the field, thereby jeopardizing the bird's reproductive success.

DeWitt and Menzie (1961 as cited in EPA, undated) reported a reduction in chick production of quail when fed diets containing a total of 12,000 mg/kg or more of carbaryl during growth, winter, and production periods. Pheasants fed diets with 500 or more ppm carbaryl during the breeding season had a 50-percent reduction in chick survival. Depressed body weights were observed in quail fed diets containing 250 ppm or more carbaryl and in pheasants fed diets containing 1,000 ppm carbaryl. The percentage of growth depression in pheasants was roughly proportional to the daily intake of carbaryl.

Japanese quail fed 50, 150, 300, 600, 900, and 1,200 mg carbaryl per kg of feed (ppm) from the day of hatching to 14 weeks of age showed growth depression and increases in relative brain, liver, and kidney weights (Bursian and Edens, 1977 as cited in EPA, undated). A slight decrease in egg production and viability was observed at the 600, 900, and 1,200 ppm levels.

Zinkl et al. (1977) also suggested that brain cholinesterase inhibition caused by treatment with 1 lb a.i./acre carbaryl may result in reduced reproductive success because birds would be unable to gather food or escape predation.

In a study involving exposure of eggs to pesticides, 40 percent of eggs injected with 5 mg of carbaryl hatched (Ghassemi et al., 1981). No eggs hatched that were injected with 2.5 mg each of malathion and carbaryl. These dosages are considered to be well above the expected environmental exposure. In another study, hen eggs injected with 100 and 200 ppm carbaryl in acetone killed 61 and 100 percent of embryos, respectively (Dunachie and Fletcher, 1969). Teratogenic effects were caused at 50 ppm and above.

Toxicity to Insects

Honey Bees. Carbaryl is very toxic to honey bees (Union Carbide, 1980). In honey bees, the 48-hour LD_{50} for direct exposure is 1.34 ug/bee for carbaryl dust and 1.02 ug/bee for Sevin 4-Oil dust (Atkins et al., 1973). Similar results were reported by Stevenson (1970). The LD_{50} for an adult bee by direct contact was approximately 1 ug or 10 to 15 mg/kg.

Carbaryl is more toxic to honey bees when ingested than from direct contact. The results of laboratory experiments indicate that the LD_{50} is 0.18 ug per bee when administered orally (Alvarez et al., 1970). Bees collecting pollen from treated areas may be killed in great numbers when walking over treated surfaces (Mayland and Burkhardt, 1970).

Older bees (normally the worker bees) are less susceptible to carbaryl (Mayland and Burkhardt, 1970) and may carry contaminated pollen to the hive before they sicken and die. The young and the reproductive members of the hive also may die from eating pollen (Johansen and Brown, 1972; Mayland and Burkhardt, 1970; Strang et al., 1968). Once inside the hive, the contaminated pollen may remain toxic for months (Johnasen and Brown, 1972; Moffett et al., 1970 as cited in Dobroski, 1985).

If bees are removed beyond flight range from an area to be sprayed and not returned for 7 days after spraying, mortality is not significant (Atkins et al., 1975, 1977 both as cited in Dobroski, 1985; Strang et al., 1968; Union Carbide, 1981). Another method to reduce the effects of spraying carbaryl near bees is the deliberate feeding of corn pollen to the bees, which seems promising on an experimental basis (Moeller, 1972). Most recommendations include either moving the colony for a brief period or confining the bees to their hive before and shortly after spraying (Agriculture Research Service, 1967, 1977).

Other Beneficial Insects. Because carbaryl acts as a broad spectrum pesticide (EPA, 1980), a certain amount of toxicity to a wide variety of insects and other arthropods may be expected. Many insects in the order Hymenoptera (this order includes the honey bees) seem to be especially susceptible to carbaryl (Abu and Ellis, 1977 as cited in Dobroski 1985; Adams and Cross, 1967; Plapp and Vinson, 1977; Stern, 1963). Ladybird beetles (Coccinellidae) also have been found to be very sensitive to carbaryl (Afify et al., 1970; Bartlett, 1963, 1966; Colburn and Asquith, 1971; Satpathy et al., 1968; Stern et al., 1959). In general, both groups of insects are regarded as beneficial insects because they act as predators and parasites of various insect pests.

Comparatively less carbaryl is required to kill these beneficial insects than is needed to kill pest insects. Even parasites developing inside a treated host insect may be killed (Abu and Ellis, 1977 as cited in Dobroski, 1985), as will ladybird beetles feeding on poisoned aphids (Satpathy et al., 1968). A loss of these predators may occur in carbaryl-treated areas, but no permanent loss has been found in monitored spray programs (Root and Skelsey, 1969; Shepard and Sterling, 1972; Union Carbide, 1980). A fairly rapid reestablishment of these beneficial insects by immigration from areas surrounding the treated area can be expected because little residual effect of carbaryl exists several days after spraying.

Carbaryl is not toxic to all members of the order Hymenoptera because at least one important pollinator of alfalfa, the alfalfa leafcutting bee, is only moderately susceptible to carbaryl (Johansen et al., 1963; Waller, 1969). Other beneficial insects, such as the predaceous big-eyed bugs (Walker et al., 1974 as cited in Dobroski, 1985) and green lacewings (Plapp and Bull, 1978 as cited in Dobroski, 1985) are not severely affected by carbaryl (Union Carbide, 1980).

Spiders and Mites. Spiders are not severely affected in carbaryl-treated fields (Shepard and Sterling, 1972), although they have been shown to be more sensitive to carbaryl when they ingest treated prey than when they walk over treated surfaces (Hangstrum, 1970). As shown in another study, spiders quickly return to treated area within 3 weeks after spraying (Barrett, 1968).

Carbaryl is highly toxic to predatory mites but not as toxic to phytophagous (plant-feeding) mites (Bartlett, 1968; Dabrowski, 1969, 1970; Dabrowski et al., 1973). One investigation (Croft and Jeppson, 1970) showed that carbaryl was less toxic to predaceous mites than was previously reported in the literature. Mite predators, such as the predaceous thrips, are also susceptible to carbaryl (Holdsworth, 1968; MacPhee and Sanford, 1961). This difference in toxicity to mite predators may cause detrimental outbreaks of phytophagous mites.

Aquatic Toxicity

Fish. The LD_{50}'s of carbaryl for a number of aquatic organisms are shown in table 2-8. The toxicity of the technical formulation is greater than the 49-percent oil dispersion formulation (Sevin 4-Oil). The acute aquatic toxicity of carbaryl is relatively low when compared to other insecticides. Members of the catfish (Ictaluridae) and minnow (Cyprinidae) families are nearly 10 times more tolerant of carbaryl than the trout (Salmonidae) family. The toxicity to sunfish and bass (Centrarchidae) is approximately midway in this range.

Acetylcholinesterase depressions (13 to 22 percent) have been observed in brook trout within 24 hours of spraying carbaryl at 1 lb/acre. Levels returned to normal within 48 hours. At the same application rate, Atlantic salmon (*Salmon salar* C.) showed average AChE depression of 20 percent. Levels did not return to normal within 48 hours (Hulbert, 1978; Marancik, 1976).

Invertebrates. Some aquatic insects in the orders Plecoptera (stoneflies) and Emphemeroptera (mayflies) are highly sensitive to low levels of carbaryl. There may be a 50- to 100-percent reduction in aquatic insect populations in treated streams and ponds (Burdick et al., 1960). Mount and Oehme (1981) found

that applications of 1.25 pounds of carbaryl per acre were not directly toxic to fish, but food items were reduced by 97.2 percent. LOTEL (1975) reported that in a stream treated with 1 pound of carbaryl per acre, each sampling station recorded a residue of at least 40 ppb and a peak residue of 80 ppb. The biological impact was indicated by increased drift of dead and dying stoneflies, mayflies, caddisflies, and true flies.

The effects of 2 consecutive years of spraying on other aquatic organisms appear similar to those observed in areas treated just once (Trial, 1978, 1979; Courtemanch and Gibbs, 1978). These effects include loss of stonefly species from individual streams and altered generic assemblages for an indefinite period (Trial, 1978, 1979). A study of buffered streams by McCullough and Stanley (1980) during the 1979 Maine spruce budworm spray project indicated that benthic invertebrate fauna were not adversely affected. Also, the numbers of drifting invertebrates were substantially lower than in previous years. The long-term impact appears to be a function of species susceptibility and recolonization ability. Two consecutive years of spraying with carbaryl reduced populations of stoneyfly and susceptible mayfly genera to near zero.

Carbaryl (Sevin 4-Oil) was applied to woodland ponds in Maine at a rate of approximately 1.85 lb a.i./acre (0.84 kg a.i./acre). Caddisfly populations were temporarily reduced. Most severely affected were the amphipods (Hyallela azteca), which were nearly reduced to zero. This group failed to recolonize in some ponds for up to 30 months after spraying (Gibbs et al., 1984).

Aquatic Plants. Carbaryl was nontoxic to a species of fresh-water algae at 1 ppm. The growth rate of the algae actually increased after exposure to carbaryl; this was thought to be a result of the increase in available nitrogen (an important plant nutrient) from the degradation of carbaryl (Stadnyk et al., 1971). An increase in algae growth rate after exposure to carbaryl also was reported by Murray and Guthrie (1980).

Concentrations of approximately 10 ppm carbaryl were lethal to three of five species of marine algae. Reproduction was not affected at 1.0 ppm. In one of the five species, growth was inhibited at 0.01 ppm (Ukeles, 1962).

Toxicity of 1-Naphthol

1-Naphthol is the major microbial degradation product of carbaryl. In a laboratory study (Stewart et al., 1967), carbaryl was shown to be 30 to 300 times more toxic than 1-naphthol to crustaceans (shrimp and crabs). In the same study, 1-napthol was twice as toxic as carbaryl to fish and mollusks (mussels, clams, and oysters) (Butler et al., 1968; Stewart et al., 1967).

Acephate

Mammalian Toxicity

Brain cholinesterase depression has been reported for small mammals after aerial spraying of acephate (0.5 lb a.i./acre) on forest plots in Idaho. Red squirrels recovered within 6 days after spraying, but Columbian ground squirrels had depressed cholinesterase levels at 25 days after spraying (Zinkl et al., 1980). Recovery of stressed individuals, such as pregnant or nursing animals, could be somewhat slower. The acephate application rate for the

Forest Service spruce budworm suppression program is 0.094 lb a.i./acre (1.5 oz a.i./acre).

Refer to the discussion about human health hazards in this section for details on the chronic toxicity, oncogenicity, teratogenicity, and mutagenicity of acephate on birds and mammals.

Avian Toxicity

Acephate is slightly to moderately toxic to birds. Hens had a reported oral LD_{50} of 360 mg/kg (304 mg/kg to 425 mg/kg) (EPA, 1984c). The oral LD_{50} for mallards is 234 mg/kg. Toxic symptoms that occurred when mallards were given lethal or near-lethal dosages included (in approximate order of onset): ataxia, imbalance, hopping and falling, jerkiness, mild spasms in the legs and feet, immobility, wing spread, and intermittent tremors (Hudson et al., 1984).

In field studies, results indicate that the effects of acephate on bird populations differ. Although no significant effects were observed in some areas, others showed significant declines in population numbers thought to be related to reduction in food supply. In addition, significant ChE inhibition was observed in several cases.

Songbird populations sprayed with acephate at rates of 0.09 to 6.5 lb a.i./acre were not adversely affected at two sites in eastern Canada. Surveys were performed for up to 6 days after spraying to detect changes in songbird populations and to identify dead or ill birds (Buckner and McLeod, 1975 as cited in Lambert, 1985).

A significant decline in red-eyed vireos occurred after treatment of a forested plot in New York with acephate at a rate of 0.5 lb a.i./acre. Whether the decline was a direct result of the pesticide or a result of a decline in the birds' food supply was not determined (Bart, 1979).

The vireo species abandoned treated areas, and singing activity of the crested flycatcher decreased after areas were sprayed with acephate. These reactions were considered responses to arthropod food supply distribution (LOTEL, 1975).

No direct mortality of wildlife was observed after aerially applying acephate at 1.5 oz a.i./acre on rangeland in Wyoming, Utah, and Arizona in 1979 and 1980, and in Wyoming in 1981 (McEwen and DeWeese, 1981). However, birds and small mammals did exhibit reduced brain cholinesterase activity in live specimens taken up to 24 days after spraying. The effects of sublethal brain cholinesterase reduction are largely unknown, but the literature indicates that the long-term biological and population effects may not be very great for depressions of less than 25 percent of brain cholinesterase. Potential short-term effects, however, could include inability to gather food, to escape predation, or to adequately care for young.

A number of other studies have reported significant depression of brain cholinesterase in songbirds following spraying of acephate at rates of 0.5 lb to 2.0 lb a.i./acre (Julin and Gramlich, 1978; Zinkl et al., 1977; Zinkl et al., 1980; Richmond et al., 1979). These rates are all well above that proposed for use by the Forest Service.

Studies by Zinkl et al. (1981) with dark-eyed juncos and by Fleming and Bradbury (1981) with mallards indicated that brain cholinesterase depression of more than 50 percent may be fatal. The latter study also concluded that there appears to be a threshold dose for acephate (and other organophosphate pesticides) that must be surpassed before inhibition of brain cholinesterase occurs. However, this threshold application rate has not yet been determined, and research has been suggested by the U.S. Fish and Wildlife Service (1986).

Recovery from acephate exposure also can be monitored by measuring brain cholinesterase over time. Recovery to about 80 percent of normal cholinesterase levels occurred within 10 days in bobwhite quail and mallards after 2 weeks on diets with 20 ppm acephate (Stelzes, 1982). However, recovery of nesting birds, which would already be stressed, may be somewhat slower.

Lambert (1985) summarized in his review of the literature that "forest applications of acephate at recommended rates of 0.5 and 1.0 lb a.i./acre can be expected to produce physiological indications of organophosphorus intoxication in forest birds." The proposed application rate for the spruce budworm suppression program of 1.5 oz a.i./acre is considerably less than these rates. Lambert also stated that recovery from sublethal doses of acephate appears to take only a few days.

Effects on Avian Reproduction. Avian reproduction studies showed no reduction in mallard egg production with 16-week dietary exposures of 5, 20, and 80 ppm technical acephate (Beavers et al., as cited in EPA, 1984d). However, duckling survival, up to 14 days of age, was reduced 20 percent at the 20- and 80-ppm levels; no effects were observed at the 5-ppm level. In bobwhite studies, egg production and chick survival were both significantly reduced at the 80 ppm level but were not affected at the 5- and 20-ppm treatment levels (Beavers et al., as cited in EPA, 1984d). In both studies, observed AChE inhibition increased with dosage and may suggest a basis for reduction in reproductive output.

Peterson et al. (1981) reported no decrease in nesting success of rangeland birds on plots sprayed with 0.1 lb a.i./acre of acephate.

Effects on Honey Bees, Wild Bees, and Other Pollinators

Acephate is highly toxic to honey bees. The 48-hour LD_{50} for topical exposure to acephate dust is 1.2 ug/bee for honey bees (*Aphis mellifera* L.) (Atkins et al., 1973). Laboratory and controlled field application tests conducted by Kupetz et al. (1979) indicated the following LD_{50} values for acephate: oral (feeding studies), 1.07 ug/g body weight; topical (direct application), 5.4 ug/g body weight; and contact (with deposit on surfaces), 3,000 ug/100 cm^2 (2.7 lb a.i./acre as deposited).

Additional laboratory studies by Arzone and Vidano (1980) indicated that acephate displayed a high oral toxicity to honey bees at doses 128 times lower than certain suggested crop-spraying application rates, and acephate residues could remain lethal to honey bees upon contact for as long as 52 hours after application.

In Canada, acephate was tested as a possible control for spruce budworm (Buckner and McLeod, 1975 as cited in Lambert, 1985). Honey bees were placed

in treated and untreated forest plots. Orthene was applied at measured ground level rates ranging from 0.1 to 6.5 lb a.i./acre. In general, honey bees suffered population reduction, and the treatment affected nurse bees within the hives. These adverse effects were recorded for 2 days, and pollen collection was curtailed for up to 5 days. The impact on honey bee colonies was temporary, and seasonal honey production was similar for treated and controlled hives.

Moffett et al. (1979) studied a number of measures to protect apiaries in areas where aerial spray applications of acephate may occur. In general, colonies directly in the path of the spray application suffered greater damage than colonies at the edges of the treated fields. Colonies close to alternate sources of pollen and nectar suffered less than colonies depending on the treated crops. Overall damage could be reduced by applying a combination of preventive management methods before and during spray application.

Acephate was tested as a candidate control chemical for the Douglas-fir tussock moth as reported by Robinson and Johansen (1978). Part of the test was to determine the effects of acephate on honey bees and other pollinators in the forest environment. Honey bee colonies in the path of aerial spray applications were all dead within 45 and 48 days after treatment, and colonies in untreated plots near the treated areas also were adversely affected. Data from this study indicated that foraging worker bees succumbed to the acephate in the field. Application rates were 1 and 2 lb a.i./acre on selected plots in the Wallowa-Whitman National Forest located in portions of the Blue Mountains and the Wallowa Mountains of northeastern Oregon (Davis et al., 1978).

The reuslts from this study are in contrast to earlier studies on plots in northern Idaho (Johansen, 1975) in which acephate applied at 0.5 lb a.i./acre resulted in relatively low honey bee mortality and residual effects were negligible. This indicates that a number of factors may have been involved that directly affected honey bee intoxication. Some of these factors include application rate, weather conditions, and time of day of application. Johansen (1977) classified acephate as a minimal hazard to honey bees if applied during late evening, night, or early morning on blooming crops. The effect depends on the presence and concentration of contaminants in the pesticide formulation (including methamidophos), and proximity of alternative sources of pollen and nectar.

The Douglas-fir tussock moth study (Robinson and Johansen, 1978) also addressed effects on other bees in the same forest plots. Bumblebees and mason bees were the prevalent wild bees, with bumblebees being the major pollinators of forest plants in the study area. Depressions in the numbers of foraging wild bees were apparent in all plots treated with acephate.

However, there was no apparent depression of wild bee populations in the same treated areas in the year following acephate application. The conclusion of the study was that a single application of acephate at an elevation of 4,000 to 6,000 feet is unlikely to cause either a severe or long-term impact because of reductions in insect pollination.

Acephate applied to three experimental plots in a northeastern Oregon forest at 1 and 2 lb a.i./acre had a devastating effect on ants of the genus <u>Formica</u> (Rousch and Akre, 1978). The insecticide was applied during relatively cool

weather. As the temperature rose, the foraging activities of the ants increased. Foraging material containing acephate was brought to the colonies, which were effectively dead 6 days after spraying. There was no recovery during the following year.

Aquatic Toxicity

Fish. Laboratory bioassays indicate that acephate is relatively nontoxic to fish, and lethal dosages are far greater than could be expected from normal spruce budworm operational application (Schoettger and Mauck, 1976). The acute LC_{50}'s of acephate for a number of aquatic organisms are shown in table 2-9. Tests by Johnson and Finley (1980) indicated that toxicity to trout, blue gill, or yellow perch was not affected by changes in water temperature, pH, or hardness.

Acephate application may change fish feeding habits (Rabeni, 1978). Quantitatively, there was an immediate postspray increase of number of prey and prey volume taken per fish. The number of terrestrial forms (beetles, moths, wasps, and particularly spiders) also increased after spraying and lasted 2 to 3 days before returning to prespray levels. Prey volume per fish remained above prespray levels throughout the study period (8 days).

Rabeni (1978) found that acephate exposure depressed brain acetylcholinesterase activity in white suckers 28 to 29 percent postspray, and AChE activity returned to prespray levels in 8 days. Acetylcholinesterase activity was not depressed in brook trout or Atlantic salmon.

Bluegill sunfish (Lepomis macrochirus Rafinesque), yellow perch (Perca flavescens Mitchill), smallmouth bass (Micropterus dolomieui Lacepede), and bullheads (Ictalurus nebulosus LeSeur) were caged in a pond and observed for 2 weeks before and after an application of 0.5 lb acephate per acre. No mortality or behavioral changes were observed in any of the fish. (LOTEL, 1975).

Aquatic Insects. An acephate application of 0.5 lb a.i./acre resulted in decreased populations of caddisflies (Trichoptera) and true flies (Diptera); the decreases were temporary and significant only for midges (LOTEL, 1975). A similar application in Maine resulted in decreased populations of caddisflies and mayflies, but reductions were temporary and not detected 9 days after treatment (Rabeni and Gibbs, 1979).

Amphibians. Amphibians in larval or adult stages were not affected by forest applications of acephate at rates of 0.5 lb and 1 lb a.i./acre (Buckner and McLeod, 1975 as cited in Lambert 1985). The 24-hour LC_{50} for tadpoles of the green frog is 6,433 mg/L (Lyons et al., 1976).

Methamidophos

Mammalian Toxicity

Acephate degrades in the environment and is metabolized in animals to methamidophos, a relatively more toxic compound. From 10 to 29 percent of applied acephate may degrade rapidly to methamidophos in the environment depending on the substrate.

Methamidophos is about 40 to 70 times more toxic than acephate in rats, and 10 times more toxic than acephate in mice (Lambert, 1985).

Avian Toxicity

Studies examining the toxicity of acephate in birds (Junco Hyemalis) have also detected residues of methamidophos (Zinkl et al., 1981). EPA has required an avian residue monitoring study because of the high levels of the metabolite methamidophos found in avian foods after a 1 lb a.i./acre application of acephate (EPA, 1985).

According to EPA (1982b), methamidophos is very highly toxic to birds and highly toxic to mammals on the basis of a single dose (bobwhite quail LD_{50} = 8 mg/kg; rat LD_{50} = 13 mg/kg). RTECS (1987) lists a rat LD_{50} of 7.5 mg/kg. Methamidaphos is very highly toxic to birds in the diet (bobwhite quail LC_{50} = 42 ppm) but only slightly toxic to mammals in the diet (rat LC_{50} = 894 ppm).

Diesel Oil

Mammalian Toxicity

Refer to the discussion in the human health hazard section of this section for details on the chronic toxicity, oncogenicity, teratogenicity, and mutagenicity of carbaryl. According to the American Petroleum Institute (1983c), the major hazards to mammals from diesel oil in the environment include the adherence of oil to the fur of animals, possibly resulting in hypothermia, and sublethal effects in small mammals from contaminated forage.

Toxicity to Beneficial Insects

Based on available studies, diesel oil appears to be highly toxic to honey bees, suggesting the potential for a high degree of toxicity to other invertebrates. Diesel oil caused high mortality to honey bees during the first 24 hours after spray treatment (Moffett et al., 1972). The authors also reported that the toxicities of the combinations of diesel oil and water or diesel oil, water, and dimethylsulfoxide (DMSO) are less than diesel alone.

The use of adjuvants, such as spray oil, diesel oil, and surfactants, with insecticides caused slightly increased mortality of honey bees (Lagier et al., 1974).

Avian Toxicity

Diesel oil is very slightly toxic to orally exposed birds. The acute oral LD_{50} of diesel oil for mallard ducks older than 1 year is greater than 16,400 mg/kg (20 ml/kg) (Hudson et al., 1984). However, traces of oil in a mallard's diet sharply reduce egg production (Biderman and Drury, 1980). Furthermore, application of 5 ul of No. 2 fuel oil on mallard eggs significantly reduced hatching success to 18 percent (control group's hatching success was 88 percent) (Szaro et al., 1978). Survival and hatchability were significantly reduced even after application of only 1 ul of oil (Szaro et al., 1978). The authors reported that application of 20 ul of No. 2 fuel oil, which covered 20

percent of the egg surface, killed all embryos. Death occurred rapidly and appeared to be related to the aromatic portion of the oil rather than the aliphatic portion. Szaro et al. (1978) reported that surviving ducklings showed no gross external or behavioral abnormalities, and no significant differences in weights in comparison with controls at hatching. Similar toxicity of diesel oil was noted in pheasant eggs, which failed to hatch when sprayed with diesel oil to the point of runoff (Kopischke, 1972). Death occurred 1 to 2 days after oil was applied.

Pesticides in a relatively nontoxic oil carrier applied to mallard eggs were more toxic to embryos than when the pesticides were applied in a water carrier (Hoffman and Albers, 1984). The greater toxicity of the pesticide-oil mixture was attributed to the oil, which presumably caused an increased level of penetration of the pesticide through the shell and its membrane.

Aquatic Toxicity

Fish. Diesel fuel, jet fuels, and fuel oils are moderately to highly toxic to fish (based on the toxicity categories of EPA, 1985). Jenkins et al. (1977, as cited in Burks, 1982) studied the acute and chronic toxicity of jet fuels to several fish species. They reported 96-hour LC_{50}'s (static tests) for the golden shiner (Notemigonus crysoleucas) of 0.68 and 0.94 mg/L for the jet fuels RJ-4 (a 12-carbon molecule) and RJ-5 (a 14-carbon molecule), respectively. They also reported a 97-day nonlethal concentration for rainbow trout (Salmo gairdnerii) of less than 0.03 mg/L for RJ-4 and 0.04 mg/L for RJ-5; and a no-effect level for eggs of the flagfish (Jordanella floridae) exposed by continuous flow to RJ-4 of 0.2 mg/L. Reduced hatchability was observed in flagfish eggs from exposure to RJ-5 at concentrations greater than 0.05 mg/l.

Acute toxicity tests with freshwater fish showing 96-hour LC_{50}'s of greater than 0.19 mg/L for diesel fuel and greater than 1.2 mg/L for No. 2 fuel oil have been reported by EPA (1976, as cited in DOE 1983). Tagatz (1961, as cited in Burks 1982) reported much lower toxicity, with a 48-hour LC_{50} for No. 2 fuel oil of 125 to 251 mg/L with juvenile American shad. His reported LC_{50} is based on the amount of oil applied to the surface of the water (nominal concentration) and not the water soluble fraction; this may account for the apparent lower sensitivity of the shad.

The toxicity of No. 2 fuel oil has been studied for a number of marine fish and invertebrate species (table 2-10). The LC_{50}'s range from 0.81 to more than 6.9 ppm for marine fish and 0.21 to 14.1 ppm for invertebrates (Connell and Miller, 1984). The range of toxicity values determined for No. 2 fuel oil with marine species is useful in estimating the range of sensitivities for freshwater species because marine and freshwater species generally have a similar range of tolerance to toxicants (Sprague, 1985).

Irwin (1964, as cited in Burks 1982) calculated a "ratio of resistance" to allow the ranking of the sensitivities of 57 fish species to oil refinery wastewater. The guppy (Lebistes reticulatus was least sensitive and was assigned a ratio of resistance of 100. The ratios of resistance for some of the common freshwater fish were as follows: rainbow trout (Salmo gairdnerii), 34.68; smallmouth bass (Micropterus dolomieui), 35.60; northern pike (Esox lucius), 37.31; fathead minnow (Pimephales promelas), 49.19; largemouth bass (Micropterus salmoides), 53.27; bluegill (Lepomis macrochirus), 54.10; and

channel catfish (Ictalurus punctatus), 60.15. This study may be useful in predicting the relative order of sensitivities of these species to diesel fuels and other petroleum products.

Aquatic Invertebrates. The 96-hour LC_{50} for adult blue crabs (Callinectes sapidus) exposed to No. 2 fuel oil was 14.1 mg/L. No histopathological changes were observed in the gills, hepatopancreas, or muscles of the blue crab after 2 weeks of exposure to No. 2 fuel oil at 0 to 1 ppm (Melzian, 1983).

A spill of No. 2 fuel oil into a small stream in Virginia was acutely toxic to some fish, crayfish, and caddisflies. At 2 weeks after the spill the density of benthic macroinvertebrates downstream was 25 percent less than the density upstream from the spill, but species diversity was not affected. The density of the macroinvertebrates had returned to normal levels by 18 weeks after the spill (Hoehn et al., 1974, as cited in Burks, 1982).

Kerosene

Avian Toxicity

Kerosene was not lethal to embryos when applied to mallard eggs at doses of to 1 to 50 ul/egg (Hoffman and Albers, 1984). The authors suggested that the low toxicity of the kerosene to embryos was related to its low aromatic hydrocarbon content. This may be evidenced by the low mortality of embryos exposed to a mixture of aliphatic hydrocarbons and the high mortality of embryos exposed to a mixture of aromatic hydrocarbons (Hoffman and Albers, 1984).

TOXICITY STUDY DATA GAPS

Data gaps for toxicity testing of malathion, carbaryl, and acephate are presented in table 2.11. Toxicity study data for the three pesticides in this hazard analysis were generally comprehensive. Adequate toxicity testing data existed to establish NOEL's for systemic and reproductive effects for the three pesticides. Toxicity study data that were not available in current literature included teratogenicity study data for malathion, reproduction study data for acephate, chromosome aberration mutagenicity study data for malathion, and primary DNA damage study data for carbaryl. The absence of this study data was not considered to have a deleterious effect on the quality of this analysis.

The study data for Bacillus thuringiensis (B.t.) generally was not specific for the delta-endotoxin (toxin used in B.t. formulation by the Forest Service); however, all study data on the delta-endotoxin available in the literature indicate that the delta-endotoxin is relatively nonhazardous to human health and wildlife.

Table 2-1-- Acute toxicity classification and acute toxicites of the three insecticides.

Toxicity category[a] (label signal words)	Insecticide or other chemical substance	Oral LD_{50} for rats (mg/kg)	Equivalent human dose
IV Very Slight		5,000-50,000 (Range)	More than 1 pint
	Sugar	30,000	
	Ethyl alcohol	13,700	
III Slight (caution)		500-5,000 (range)	1 ounce to 1 pint
	Table salt	3,750	
	Bleach	2,000	
	Aspirin, Vitamin B_3	1,700	
	Acephate	866	
II Moderate (warning)		50-500 (range)	1 teaspoon to 1 ounce
	Malathion	370	
	Carbaryl	270	
	Caffeine	200	
I Severe (danger - Poison)		0-50 (range)	1 teaspoon or less
	Nicotine	50	
	Strychnine (rodenticide)	30	
	Botulinus toxin	0.00001	

[a] Category, signal word, and LD_{50} ranges are based on a classification system that EPA uses for labeling pesticides.

Source: Adapted from Maxwell (1982).

Table 2-2--Laboratory-determined toxicity levels for threshold effects.

Insecticide	Acute oral LD_{50} in rats	Lowest systemic NOEL	Lowest reproductive and/or teratogenic NOEL
Acephate	866 mg/kg (EPA, 1984c)	5 ppm (0.25 mg/kg/day), 28-month oncogenic rat study (Federal Register 47(227): 52994-5.)	No teratogenic effects in 2 studies with rats and rabbits. Teratogenic NOEL greater than 200 mg/kg/day, highest dose tested (EPA, 1984c) Maternal NOEL - 3 mg/kg/day, rabbit teratology study (EPA, 1984c)
Carbaryl	270 mg/kg (EPA, 1984a)	1.8 mg/kg/day, 1- year dog feeding study (EPA, 1984a)	Teratogenic NOEL of 3.125 mg/kg; maternal NOEL less than 3.125 mg/kg, dog teratology study (EPA, 1984a; Smalley et al., 1968) Teratogenic NOEL - 2 mg/kg; maternal NOEL less than 2 mg/kg, dog teratology study (EPA, 1984a)
Malathion	370 mg/kg (NLM, 1986a)	0.2 mg/kg/day, 47-day human ingestion study (Moeller and Rider, 1962)	Reproductive and fetotoxic NOEL - 500 ppm (25 mg/kg/ day), three-generation rat reproduction study (DHEW, 1976).

Conversion factor: rat 1 ppm - 0.5 mg/kg/day.

Table 2-3--Laboratory-determined toxicity levels for nonthreshold effects.

Insecticide	Cancer potency[a] (1mg/kg/day)-1	Mutagenicity Assays
Acephate	0.0093	Positive in mutagenicity assays using human and mammalian cells in vitro and in vivo, and in microbial cells in vitro.
		Weakly positive in microbial assays. Negative results for human and mammalian cells in vitro, and in vivo, and in microbial cells (EPA, 1984c).
Carbaryl	0.076[b]	Negative in an in vitro mammalian assay system (1Epstein et al., 1972).
		Positive in chromosomal assays (EPA, 1984a).
Malathion	0.02	Negative in microbial assays and positive in in vitro human cell assay (American Cyanamid Company, 1986).
		Negative in mutagenic assays (Ames Samonella Assay) (Pedlnekar et al., 1987).

[a] Converted from animals to humans according to a body surfface area scaling rule.

[b] Assuming 1 percent of ingested carbaryl is converted to N-nitrosocarbaryl in the stomach (Lijinsky and Taylor, 1986).

Table 2-4--Mutagenicity testing on the three pesticides

Mutagenicity test type[a]	Value in determining human mutagenicity	Pesticide: Malathion	Carbaryl	Acephate
Group 1--Tests for detecting gene mutations				
A. Bacteria with and without metabolic activation	+	8(-)	2(+)[c]	4(+)1(-)
B. Eukaryotic microorganisms with and without metabolic activation	+			
C. Insects (e.g., sex-linked recessive lethal test)	++	6(-)		
D. Mammalian somatic cells in culture with and without metabolic activation	++			1(+)
E. Mouse specific locus test in vivo	++			2(-)
Group 2--Tests for detecting chromosomal aberrations				
A. Cytogenetic tests in mammals in vivo	++		d	1(+)3(-)
B. Insect tests for heritable chromosomal effects in vivo	++			
C. Dominant-lethal effects in rodents, heritable translocation tests in rodents, and in vitro cytogenetic assays in mammals	++		1(-)	1(-)[e]
Group 3--Tests for detecting primary DNA damage				
A. DNA repair in bacteria (including differential killing of DNA repair defective strains) with and without metabolic activation	NA			
B. Unscheduled DNA repair synthesis in mammalian somatic cells in culture, with and without metabolic activation	NA			1(+)1(-)
C. Mitotic recombination and gene conversion in yeast, with and without metabolic activation	NA			1(+)
D. Sister-chromatid exchange in mammalian cells in culture, with and without metabolic activation	NA	1(+)		1(+)1(-)

NA = Not applicable.
\+ = Applicable.
++ = Greater applicability.
Note: Sources for mutagenicity data are given in the text discussions of nonthreshold effects.

[a] Source: FIFRA, Environmental Protection Agency: Proposed Guidelines for registering pesticides in the U.S. Hazard Evaluation? humans and domestic animals. Fed Reg. 43:37335-37403, August 22, 1978.
[b] Source: Brusick. (see list of preparers)
[c] Tests were performed on N-nitrosocarbaryl
[d] An unspecified test regimen was reported to be positive for mitotic effects and chromosomal aberrations (EPA, 1984a).

Table 2-5--Comparative oral toxicity of acephate (Orthene) and methamidophos (Monitor)

	LD_{50} (mg/kg body weight)	
Animal Tested	Acephate	Methamidophos
Mouse	150-361	14
Rat, Male (Sprague Dawley)	945-1,100	15.6-23.4
Rat, Female (Sprague Dawley)	866	13-18.9
Chicken	568-852	27.5
Dark-Eyed Junco	106	8

Source: Etter and Tissier, 1973, as cited in Lamber, 1985; Adair and Rich, 1977; Larson, 1975; Zinkl et al., 1981; Berteau and Chiles, 1978.

Table 2-6--Acute toxicity of malathion to aquatic organisms[a]

Organism	Water temperature (°C)	Stage or weight (grams)	96-hour LC_{50} (ug/L) (95% confidence interval)
		Fish	
Rainbow trout	12	1.4	200 160-240
Cutthroat trout	12	1.0	280 270-310
Brown trout	12	1.1	101 84-115
Lake Trout	12	0.3	76 47-123
Channel catfish	18	1.5	8,970 16,780-12,000
Black bullhead	18	1.2	12,000 10,700-15,600
Yellow perch	18	1.4	263 205-338
Walleye	18	1.8	64 59-70
Largemouth bass	18	0.9	285 254-320
Bluegill	18	1.5	103 87-122
Green sunfish	18	1.1	175 134-228
Redear sunfish	24	3.2	62 58-67
Fathead minnow	18	0.9	8,650 6,450-11,500
Carp	18	0.6	6,590 4,920-8,820
Goldfish	18	0.9	10,700 8,340-13,800

Invertebrates

Simocephalus (daphnid)	15	First Instar	3.5[b] 2.6-4.8
Daphnia magna (Daphnid)	15	First Instar	1.0[b] 0.7-1.4
Daphnia pulex (daphnid)	15	First Instar	1.8[b] 1.4-2.4
Cypridopsis (seed shrimp)	21	Mature	47[b] 32-69
Asellus (sowbug)	21	Mature	3,000 1,500-8,500
Grammarus fasciatus (scud)	21	Mature	0.76 0.63-0.92
Orconectes (crayfish)	15	Early Instar	180[c] 140-230
Palaemonetes (grass shrimp)	21	Mature	90[c] 67-120
Pteronarcys (stonefly)	15	Second Year class	10 7.0-13
Pteronarcella (stonefly)	15	Naiad	1.1 0.8-1.5
Claassenia (stonefly)	15	Second Year class	2.8 1.4-4.3
Isoperla (stonefly)	15	First Year class	0.69 0.20-2.4
Lestes (damselfly)	15	Juvenile	10 6.5-15
Hydropsyche (caddisfly)	15	Juvenile	5.0 2.9-8.6
Limnephilus (caddisfly)	15	Juvenile	1.3 0.8-2.0
Atherix (snipe fly)	15	Juvenile	385 246-602

Amphibians

Woodhouses' toad (*Bufo woodhousii*)[d]	15.5	--	420

[a] Technical material, 95 percent.
[b] 48-hour EC_{50}
[c] Tested in hardwater (162-272 ppm $CaCO_3$).
[d] lMulla and Mian, 1981.

Sources: Johnson and Finley, 1980; Mulla and Mian, 1981.

Table 2-7--Acute oral toxicity of carbaryl in mammalian and avian species.

Animal tested	LD_{50} [a] (mg/kg)
Mammals	
Cat	150
Rat	250
Mouse	275
Mule Deer [b]	200 to 400
Rabbit	710
Birds	
Mallard	>2,564
Pheasant	>2,000
Rock dove	1,000-3,000
Chukar	(1,498-2,378)
Japanese quail	2,290 (1,740-3,020)
Sharp-tailed grouse	780-1,700
Canada goose	1,790 (1,480-2,180) [c]

[a] Numbers in parentheses are the 95-percent confidence intervals.
[b] Female, age = 11 months.
[c] 50 percent carbaryl.

Sources: NLM, 1986b; Hudson et al., 1984; Ghassemi et al., 1981.

Table 2-8--Acute toxicity of carbaryl to aquatic organisms.

Organism	Water temperature (°C)	Stage or weight (grams)	96-hour LC_{50} (ug/L) (95% confidence interval)
Fish			
Rainbow trout[a]	12	1.5	1,950 1,450-2,630
Brook trout[a]	12	0.8	2,100 1,680-2,620
Brook trout[b]	12	1.3	4,500 3,948-5,066
Brook trout[c]	--	--	1,100-1,500
Cutthroat trout[a]	12	0.5	7,100 5,240-9,620
Cutthroat trout[c]	--	--	1,500-2,200
Brown trout[a]	12	0.6	6,300 5,520-7,190
Brown trout[c]	--	--	2,000
Lake trout[a]	12	1.7	690 520-910
Channel catfish[a]	18	1.5	15,800 13,900-18,000
Black bullhead[a]	18	1.2	20,000 18,000-24,000
Bluegill[a]	18	1.2	6,760 5,220-8,760
Bluegill[b]	17	0.7	39,000 29,732-51,157
Green sunfish	18	1.1	11,200 8,140-15,500
Yellow perch[a]	12	0.6	5,100 4,520-5,760
Largemouth bass[a]	18	0.9	6,400 4,400-9,200
Black crappie[a]	18	1.0	2,600 1,180-5,700
Fathead minnow	18	0.8	14,600 11,700-19,800
Carp[a]	18	0.6	5,280 4,620-6,050
Goldfish[a]	18	0.9	13,200 8,310-20,800

Invertebrates

Simocephalus[a,d] (daphnid)	16	First Instar	7.6 6.2-9.3
Daphia pulex[a,d] (daphnid)	16	First Instar	6.4 4.5-8.9
Cypridopsis[a,d] (seed shrimp)	21	Mature	115 74-179
Asellus[a] (sowbug)	18	Mature	280 214-367
Gammarus lacustris[a] (scud)	21	Mature	22 16-30
Gammarus fasciatus[a] (scud)	21	Mature	26 16-39
Procambarus[a] (crayfish)	12	Early Instar	1,900 1,160-3,110
Palaemonetes[a] (glass shrimp)	21	Mature	5.6 3.6-8.3
Pteronarcella[a] (stonefly)	16	Naiad	1.7 1.4-2.4
Pteronarcys[a] (stonefly)	16	Second Year class	4.8 3.0-7.7
Claassenia[a] (stonefly)	16	Second Year class	3.9-8.1
Skwala[a] (stonefly)	12	Naiad	3.6 2.4-5.5
Skwala[b] (stonefly)	7	First Year class	9.2 7.4-12.0

[a] Technical material, 99.5 percent.
[b] Oil dispersion, 49 percent.
[c] EPA, 1973, as cited in Dobroski, 1985.
[d] 48-hour EC_{50}

Table 2-9--Acute toxicity of acephate to aquatic organisms.

Organism	Water temperature (^{o}C)	Stage or weight (grams)	96-hour LC_{50} (ug/L) (95% confidence interval)
	Fish		
Rainbow trout[a]	10	1.5	1,100 775-1,561
Rainbow trout[b]	10	1.2	730 580-920
Brook trout[a]	12	0.2	>100
Cutthroat trout[a]	12	0.7	>100
Cutthroat trout[b]	12	0.9	>100
Channel catfish[a]	22	2.0	>1,000
Channel catfish[b]	22	0.5	560-1,000
Bluegill[a]	20	0.4	>1,000
Bluegill[b]	20	0.4	>1,000
Yellow perch[a]	12	2.0	>50
Yellow perch[b]	12	1.8	>100
Largemouth bass[c]	--	--	1,725
Fathead minnow[a]	20	1.0	>1,000
	Invertebrates		
Gammarus pseudolimnaeus[b]	12	Mature	>50
Pteronarcella[a]	12	Naiad	9.5 7.3-12.3
Skwala[a] (stonefly)	7	Naiad	12
Skwala[b]	7	Naiad	12 8.0-18
Chironomus[a] (Midge)	20	Fourth instar	>1,000
	Amphibians		
Green frog tadpoles (*Rana elamitans*)[d]	--	--	6,433

[a] Technical Material, 94 percent.
[b] Soluble Powder, 75 percent.
[c] Orthene 75S. Chevron, 1976, as cited in Lambert 1985.
[d] 24-hour LC_{50}. Lyons et al., 1976, as cited in Lambert, 1985.

Sources: Johnson and Finley, 1980; Lambert, 1985.

Table 2-10--Toxocity of light fuel oil to aquatic organisms.

Species	Concentration (ppm)	Effect	Source
Freshwater fish	>0.19[a] 1.2[d]	96-hr LC_{50} 96-hr LC_{50}	EPA, 1976, as cited in DOE, 1983
Rainbow trout	<0.03[b] 0.04[c]	97-day nonlethal level 97-day nonlethal level	Jenkins et al., 1977, as cited in Burks, 1982
Dolly Varden trout smolts	2.29[d]	96-hr LC_{50}	Connell and Miller, 1984
Pink salmon	0.81[d]	96-hr LC_{50}	Connell and Miller, 1984
Golden shiner	0.68[b] 0.94[c]	96-hr LC_{50} 96-hr LC_{50}	Jankins et al., 1977, as cited in Burks, 1982
Sheepshead minnow	>6.9[d]	96-hr LC_{50}	Connell and Miller, 1984
Saffron cod	2.93	96-hr LC_{50}	Connell and Miller, 1094
Flagfish (eggs)	0.2[b] >0.05[c]	No effect level; reduced hatchability	Jenkins et al., 1977, as cited in Burks, 1982
Blue crab	14.1	96-hr LC_{50}	Melzian, 1983
Grass shrimp larvae post larvae adult	 1.2[d] 2.4[d] 3.5[d]	96-hr LC_{50}	Connell and Miller, 1984
Brown shrimp late juvenile adult	 2.9[d] 4.9[d]	96-hr LC_{50}	Connell and Miller,
Dark shrimp	1.11[d]	96-hr LC_{50}	Connell and Miller, 1984
Humpback shrimp	1.69[d]	96-hr LC_{50}	Connell and Miller, 1984

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Table 2-10--Toxocity of light fuel oil to aquatic organisms.

Species	Concentration (ppm)	Effect	Source
Scooter shrimp	0.53[d]	96-hrLC_{50}	Connell and Miller, 1984
Pinkshrimp	0.21[d]	96-hr LC_{50}	Connell and Miller, 1984
Polychaete (segmented aquatic worm)	2-4.2[d]	96-hr LC_{50}	Connell and Miller, 1984

[a] Diesel fuel.
[b] Jet fuel RJ-4.
[c] Jet fuel RJ-5.
[d] No. 2 fuel oil.

Table 2-11--Data gaps in toxicity testing for malathion, carbaryl, and acephate.

Data gaps	Insecticide		
	Malathion	Carbaryl	Acephate
Chronic			
Rat			
Dog	X		
Oncogenicity			
Rat			
Mouse			
Reproduction			
Rat			X
Teratogenicity			
Rat	X		
Rabbit	X		
Gene Mutation		[a]	
Chromosome Abberation	X		
DNA Damage		X	

Note:
X = Data present.
[a] Tests were performed on N-nitrosocarbaryl.

Section 3

EXPOSURE ANALYSIS

This section gives the detailed information and calculations used to estimate insecticide exposure to humans, wildlife, and aquatic organisms that could occur in spraying operations for spruce budworm suppression.

The first subsection contains the basic background information used in defining the exposure-analysis methods. The terminology of insecticide use is included in this subsection. The second subsection describes the mathematical models used to estimate the transport of each chemical and its fate in various environmental components. The third subsection presents the assumptions and calculations used to estimate exposures and resultant doses to humans. The fourth subsection gives wildlife exposures, and the fifth discusses aquatic exposures.

FACTORS AFFECTING HUMAN AND ENVIRONMENTAL EXPOSURE

Background/History

The western spruce budworm, *Choristoneura occidentalis* (Freeman) is one of the most widely distributed and destructive defoliatiors of coniferous forest in North America (USDA, 1987a). *C. occidentalis* is one of eight budworm species that feed on foliage and cones of conifers in North America (Harvey, 1985). Although budworms feed on many conifers, six species are most heavily infested: Douglas-fir, grand fir white fir, subalpine fir, Engelman spruce, and western larch (USDA, 1987b). Harvey (1985) reports, however, that the distribution of *C. occidentalis* does not extend much beyond the range of its principal host, Douglas-fir (Harvey, 1985; USDA, 1987b). The range of *C. occidentalis* encompasses southwestern, central, and northern Oregon; Washington; Southern British Columbia; and the Rocky Mountain states south to New Mexico and Eastern Arizona. This risk assessment focuses on Region 6 of the Forest Service; the areas to be discussed in detail here will primarily be the States of Washington and Oregon.

Budworms are native to North American fir stands, the budworm population levels are normally held in check by the combined influences of parasites, predators, timber stand conditions, the weather. Periodic outbreaks occur because of imbalances in this control complex (USDA, 1987a). Outbreaks of western spruce budworm in the Pacific Northwest are not a recent phenomenon; the first outbreak in the Pacific Northwest lasted from 1943 to 1948, and an estimated 2000,000 acres were defoliated. Since 1947, most areas have a fairly complete defoliation history based on aerial detection surveys. Since that time, most infestations have lasted only a few years. Outbreaks typically last from 6 to 10 years (USDA, 1987a).

At epidemic levels, Budworms may defoliate entire timber stands, feeding primarily on new needle growth and affecting primarily Douglas-fir, grand-fir, and white fir. Damage to host trees may include growth loss, top kill, deformity, reduced seed production, and mortality (USDA, 1987a). Visible defoliation from 1970 to 1985 covered an area in Oregon and Washington of more than 16.8 million acres, concentrated primarily in three areas: the Blue Mountains in northeast Oregon, the Cascades in eastern Oregon, and the Cascades in eastern Washington (USDA, 1987a). Because forest management is based on forecasts of productivity, or projections of forest growth and yield (i.e., annual harvest is calculated from projected timber supply), budworm defoliation must be addressed to maintain the economic vitality of forest industries (MacLean, 1985).

Records indicate that management actions to suppress budworms in the Pacific Northwest began in 1949, when DDT was the insecticide of choice (USDA, 1987a). From 1949 until 1962, DDT was applied to more than 4.7 million acres in Washington and Oregon (USDA, 1987a). From 1976 until the present, a variety of insecticides have been used for budworm control, including malathion ULV, Sevin 4-Oil (carbaryl), Orthene (acephate), and Zectran (mexacarbate). In addition, a microbial insecticide, <u>Bacillus</u> <u>thuringienis</u> (<u>B.t.</u>), has been used. Table 3-1 lists the potential insecticides to be used in the Oregon/Washington budworm suppression effort.

This section will discuss the characteristics of the target species, the host species and their environment, and the spray program itself, and will explain how these characteristics may affect the potential for human environmental exposure.

<u>Characteristics of the Target Species</u>

The timing of the budworm life cycle varies considerably over its range, probably because of climatic variations (USDA, 1985a). In the northwest, the life cycle of the budworm, from egg to adult, occurs within 1 year (USDA, 1987a).

A few days after moths emerge in late July or early August, mating occurs and the female deposits her eggs on the underside of conifer needles. Eggs are laid in masses containing anywhere from 3 to 130 eggs, with an average of 25 to 40 (USDA, 1985a). Females usually lay some eggs where they emerge and mate, but they will fly elsewhere to deposit the remaining eggs (USDA, 1985a).

After about 10 days, the eggs hatch (USDA, 1985a). The emerging larvae spin silken shelters in branch scars, under bark scales, and among lichens on limbs and boles of the host tree where, with lowering temperatures, they will hibernate for the winter (USDA, 1985a). In early May, with warming temperatures, the larvae emerge and begin active feeding. Although budworms prefer succulent new growth, they also will feed on older foliage if new foliage is in short supply (USDA, 1985a). Some larvae also feed on pollen cones and seed (USDA 1985a). To accommodate their active growth, the larvae shed their skins (molt), usually a maximum of 5 times. The six intervening periods between molts are known as instars. After about 30 to 40 days, larvae are full grown and enter the pupae stage. Budworms pupate in webs of silk spun either at the last feeding site or elsewhere on the tree. The pupae stage lasts around 10 days, after which the moths emerge and begin the cycle again

(USDA, 1985b). Spray programs are used during the 30- to 40- larval feeding stage. The exact date of spraying is determined by weather and other environmental conditions (discussed later in this section).

Characteristics of the Host Species and their Environment

The western spruce budworm feeds on all age classes of may conifer species(USDA, 1987a). In the Pacific Northwest, budworm outbreaks occur in three major forest types: the true fir/Douglas-fir type, characterized by the host species; the ponderosa pine type, characterized by a true fir and Douglas-fir understory; and the white-fir type (USDA, 1985a).

There are a number of relationships between site/stand characteristics an infestation/damage by spruce budworm. Studies have shown a correlation between stand density and infestation (USDA, 1985a). Dense stands (increased crown closure) are more susceptible and vulnerable than open stands. In addition, mature stands, with larger stem and crown diameters, are more susceptible than younger stands. Spraying of these dense stands would provide for greater interception of insecticide by the overstory, with less of the insecticide available for penetration to understory (where nontarget vegetation, fish and wildlife, and humans would be affected). Also, host stands of small acreage isolated in non host types have been found to be less susceptible than large, contiguous blocks of a host type. Because the most effective strategy is to spray the larger strands the chances of missing the target areas and inadvertently spraying nontarget locales are much reduced, thus limiting the potential for human and environmental exposure.

In addition to the target trees, the target area contains a number of important plant species. Indians on reservations within the area, and perhaps individuals outside the reservations harvest a number of edible plants (fruits and berries). A list of these plants is included in table 3-2. Additionally, there is a variety of vegetation in the riparian zones (that is, the area bordering streams, lakes, and wetlands that acts as a transitional area between the aquatic and upland zones) that is important as a source of food, cover, shade and woody debris for fish and wildlife; for stabilization of banks; and most importantly, as a filter to sediment transport from upland areas to streams (this would help prevent runoff of insecticide-contaminated material from entering adjacent streams). Riparian plant communities may be dominated by herbaceous species (mainly rushes, sedges, and grasses); hardwood species (mostly alder, bigleaf maple, willows, Oregon ash, or black cottonwood); or coniferous species (primarily western hemlock, sitka spruce, or western red cedar).

Thousands of miles of streams form the aquatic zones in the target areas and provide a home for a variety of aquatic lifeforms. These streams are habitat for a variety of game fish, including chinook salmon (Onchorhynchus tshawytscha), steelhead trout (Salmo gairdneril), and native trout. Aquatic insects upon which these fish feed include mayflies (Ephemeroptera), caddisflies (Trichopters), stoneflies (Plecoptera), true flies (Diptera), and damsel and dragonflies (Odonata). In addition to these streams, several major reservoirs in the area provide drinking water for a number of cities, and are used for recreation and livestock purposes.

Terrestrial wildlife species in the potentially affected areas include mule deer, black-tailed deer, black bear, silver grey squirrel, Rocky Mountain elk, California quail, mountain quail, blue grouse, spruce grouse, ruffled grouse, turkey, cougar, bobcat, lynx, and bighorn sheep (USDA, 1987a).

Land in the area is held by both private and public owners. Much of the land is used for forest management (USDA, 1987a). The target areas are relatively remote from population centers and residential areas. Compared with similar efforts used to suppress gypsy moth in the northeastern United States, the spruce budworm efforts would affect a significantly lower population density. The population density in even the most rural settings in the gypsy moth project is estimated to be 0.2 people per acre (1 person per 5 acres), while an average of 1 person per 75 acres may be found in the typical budworm spray areas. The potentially affected population includes residents within or adjacent (within one-quarter of a mile) to the National Forest boundaries (USDA, 1987a) and individuals engaged in firewood gathering and recreational activities, such as camping hiking, fishing hunting swimming, and boating (USDA, 1987a).

Characteristics of the Pesticide Application Program

The various insecticides are proposed to be applied by helicopter or fixed-wing aircraft. Seed orchards and campgrounds may be treated with ground methods, such as backpack spraying. For aerial application only aircraft capable of maneuvering and operating at slow airspeeds close to the tree canopy would be used; for example, a Bell 205 helicopter or a Turbo thrush fixed-wing aircraft. At slower airspeed pilots can more easily identify hazards and treatment boundaries and can quickly shut-off insecticide spray if necessary. In addition, low elevation application over treatment areas minimizes insecticide drift both within and away from target areas. Finally, observation aircraft flying at low speeds and elevations can more easily monitor insecticide release, deposition, and drift, and can not any mechanical problems that may be affecting appropriate application. Therefore, average air speed will be maintained between 80 and 100 mph and the aircraft will dispense the insecticides at a height of about 50 to 75 feet above the vegetation. Electronic rotary atomizer spray nozzles will be used to deliver the insecticides. Median drop size will range from 100 to 150 microns in diameter. The anticipated maximum payload per aircraft will be 200 gallons. The largest area in a single watershed to be sprayed in 1 day will be 5,000 to 6,000 acres. The average swath will be maintained at approximately 100 feet, with 100-foot buffers maintained from private land and 500-foot buffers maintained from occupied dwellings. No buffer will be employed when using *B.t.*

The insecticides will be applied only when weather conditions favor effective insecticide penetration and dispersal into target areas. Operations will be prohibited when any one of the following conditions exist in the treatment area (insecticide label restrictions will take precedence over the conditions listed below when label restrictions are more limiting):

- Wind velocity is zero or exceed 8 mph.
- The air temperature exceeds 70°F or is less than 32°F.
- Rain is predicted within 6 hours after application.
- Fog or other weather conditions limit visibility.
- Relative humidity is less than 50 percent.

- The air turbulence (thermal updrafts, and so forth) is so great
- That it affects normal application.
- Low elevation air inversion is evident.
- Foliage is so wet that drops of water from at needle ends.

Before insecticide application, all application aircraft are calibrated and characterized. Calibration is the adjustment of the spray system so that the proper amount of insecticide is applied per unit area. Characterization is the evaluation of spray droplet size and determination of effective swath width. Also before application, the area to be sprayed (the spray block) is determined and ground observation, spray card, and plot tree locations (used for checking deposition and drift of applied material) are sited and established.

The pesticides will be stored in large storage tanks from which tank trucks will load the material for transfer to the location of the aircraft. The batch truck operator, mechanic/laborer, and load checkers will be involved in the pesticide transfer operations. After confirmation of weather details and examination of aircraft specifications, the application can begin. Numerous workers are involved in the spray operations. Table 3-3 lists these individuals and their estimated exposure times. Workers with the greatest exposure potential include the aircraft personnel (application pilot, aerial observers and observation pilot), load checkers, ground observers, spray assessment crew, the biological (entomology) evaluation crew, the batch truck operator, and mechanics and laborers.

Ground observers are stationed outside of the spray block to monitor application and record weather information. The spray assessment crew (card crew) also is in the vicinity during application, but this crew is outside the actual treatment unit. These individuals wait in trucks for the material to dry on the spray cards (approximately 2 hours) before entering the treatment area to retrieve the cards. The card crew usually handles approximately 150 cards per spray day. For a spray area of approximately 150,000 to 200,000 acres, this would be repeated for 30 to 40 spray days. The period of actually contacting or brushing against treated vegetation will not exceed 1/2 to 1 hour per day. These cards will be analyzed to determine deposition and drift.

Finally, approximately 14 to 21 days after spraying, the biological evaluation (entomology crew) enters the spray area to assess larval mortality. The crew uses poles to clip branches instead of climbing trees. Foliage handling is limited to bud counting, placing the branch in the bag, and shaking the bag to dislodge larvae fro counting.

Both before and during the insecticide application, the potential for accidents exists, thereby increasing the potential for exposure to the insecticides. Accidents may occur before the actual application; for example, a truck transporting insecticide to a aircraft site may be involved in an accident that results in a chemical spill.

During airborne application, accidents may occur because of mechanical failure of the aircraft, human error on the part of the pilot, or environmental conditions. Mechanical failure may result in loss of power or loss of maneuverability, or malfunctioning of the insecticide release mechanism, causing unintentional release. Mechanical failure may result in crash landing, unintentional release of spray in nontarget areas, or release of the payload.

Human error may be the result of pilot misjudgments, causing loss of aircraft control, on unintentional insecticide release in nontarget areas. Finally, unforeseen environmental conditions may occur, such as strong gusts of wind, which may cause insecticide spread to nontarget areas or a plane crash.

Insecticide Characteristics

Most insecticides are packaged and sold by the manufacturer as a concentrate in liquid form, with a specified number of pounds of active ingredient per gallon of concentrate and with inert ingredients forming the remaining portion.

Before application, insecticides are mixed with a carrier (water for malathion and acephate and diesel oil for carbaryl) according to the manufacturer's label instructions for the particular treatment purpose and the desired application rate in pounds of active ingredient per acre. Insecticide concentrate, stored in 30- to 55-gallon drums, is prepared for application and then is transferred to application equipment by a mixer/loader, who uses a batch truck that has separate storage tanks for the carrier and for the insecticide mixture.

Exposure and Dose

For a human to receive a toxic insecticide dose, two primary conditions are necessary. First, the insecticide must be present in a person's immediate environment so that it is available for intake, such as in the air a person breathes, on a person's skin, or in a person's food or water. The amount of insecticide present in a person's immediate environment is the exposure level. Second, an insecticide must get into a person's body by some route. If an insecticide is in the air, it may be inhaled into the air passages and lungs if it is on the clothing or skin, it may penetrate the skin; if it is on food or in water it may be consumed. The amount of insecticide that moves into the body by any of these routes constitutes the dose.

Thus, although two people may be subjected to the same level of exposure--for example, two ground observers--one may receive a much lower dose than the other by wearing protective clothing, using a respirator, or washing immediately after spraying. Exposure, then, is the amount of insecticide available to be taken in; dose is the amount the actually enters the body.

Potential Routes of Human Exposure

The routes of exposure considered in this risk assessment in estimating doses to workers and the public that might occur during routine operations or in the event of an accident are listed in table 3-4 and are described below.

Potential Human Exposure From Routine Operations

The greatest doses to humans in routine insecticide applications are to workers who may be exposed while: (1) mixing and loading insecticide into application equipment, (2) applying insecticide using aircraft or (3) supervising or monitoring aerial insecticide applications. In general, the use of protective clothing and equipment and adherence to proper cleanup procedures and label precautions lead to significant reductions in doses to workers.

The most significant source of exposure to persons who do not handle the insecticide containers or spray equipment in routine operations is from off-target drift of airborne insecticide spray droplets. Spraying only under favorable weather conditions reduces the amount and extent of drift.

During routine operations, workers may be dermally exposed to an insecticide if the insecticide concentrate, mixture, or drifting spray droplets contact the skin or if the insecticide is brushed off of sprayed vegetation. Inhalation exposure may result from breathing without protective devices in the area of the drifting spray droplets or where there are vapors from a volatile insecticide. However, a variety of studies have shown that inhalation exposure is very small compared with dermal exposure.

Members of the general public who are within the area of drift of the spray droplets may also receive dermal and inhalation exposure, but their exposures are likely to be relatively low compared to the exposures of workers directly involved in the spraying operations.

Insecticide may be ingested by members of the public from food containing insecticide residues. Food items such as garden vegetables, wild berries, or game animals may have received some level of insecticide from spray drift. Game animals may have fed on plants from the spray area. Ingestion exposure could also result from drinking water or eating fish from a body of water exposed to insecticide drift.

Potential Human Exposure from Accidents

If an accident occurs, workers and members of the public may be exposed to much greater amounts of insecticide than they would under normal circumstances. Workers who spill the concentrate or some of the prepared spray mixture on their skin during mixing, loading, or spraying operations or who are doused when a transfer hose breaks would be dermally exposed. Workers or members of the public who are accidentally sprayed with insecticide because they are beneath a spray aircraft also would receive a dermal dose.

The dermal dose would depend on the concentration of insecticide in the spray mix, the area of the sprayed person's exposed skin, the extent to which the person's clothing absorbed insecticide (some clothing is water repellent, but other material would permit penetration of the insecticide to the skin), and the time that elapses before the person can wash. Indirect dermal (reentry) exposure may occur if workers or members of the public brush against wet vegetation in the sprayed area.

Members of the public may be accidentally exposed to the insecticide by eating food or drinking water that has been directly sprayed. For example, members of the public may eat berries that have been directly sprayed, or they may eat meat from deer that have recently foraged on a sprayed site. Exposure to even higher levels of insecticide is possible if a container of insecticide concentrate were to break open and spill into a drinking water supply.

MODELING OF ENVIRONMENTAL TRANSPORT AND FATE

Spray Equipment and Spray Sites

In the spruce budworm suppression program, a variety of helicopter and fixed-wing aircraft are used for insecticide application. The choice of aircraft depends on a variety of factors, including the size of the area to be sprayed, volume per acre, topography, ferrying distance, available time, and the availability of aircraft.

The number of acres treated with insecticide each year in the spruce budworm suppression program can be quite large, but for the purpose of calculating exposures, it was desirable to identify typical treatment areas that represent spraying occurring on a single day in a single contiguous area. These areas were chosen to represent an amount that reasonably can be sprayed under favorable conditions. In practice, the area sprayed on a particular day (approximately 2,500 acres in 2 hours of spraying) is often smaller; occasionally it is larger.

The altitude of aircraft during insecticide application is typically 50 to 75 feet above the canopy. The altitude sometimes must be adjusted for topography because uneveness or for safety reasons. Rotary atomizer nozzles are used forapplication. The maximum pesticide load of a helicopter is 200 gallons of mixture.

Modeling of Insecticide Spray Drift

Estimation of spray drift is necessary to calculate exposure downwind of a spray site. The exposures considered in the EIS required estimating residues on the surfaces of people, animals, and plants; in water; and in the air.

The amount of insecticide that drifts downwind of a sprayed area depends on several important factors, including the following:

- Aircraft and spray systems characteristics
- Spray formulation
- Meteorology
- Release height
- Canopy characteristics
- Topography

The pattern of insecticide deposition downwind of a spray aircraft can be quite complex, especially in areas close to the flight line where deposits are heaviest. The initial distribution of the spray cloud in the first few seconds after release is controlled by the interaction of the spray with the aircraft wake. Helicopters produce not only a vertical downwash of air, but strong vortices originating from the rotor tips. The nature of the wake depends on the characteristics of the helicopter, especially its weight and rotor diameter, as well as its height and flight speed. At slow speeds the vertical downwash is quite strong, but at the speed typically used for spruce budworm spraying (80 to 100 mph), the wake forms a pair of tubular vortices that resemble those produced by fixed-wing aircraft. The aircraft wake also interacts with vegetation and is impeded by forest canopies.

Transport of the spray depends on the interaction of the wake with characteristics of the spray, which are determined by the chemical formulation and the spray equipment type and usage. The droplet sizes produced by the

system are a principal consideration in controlling drift and in providing proper coverage to ensure efficacy. The distribution of droplet sizes can be only partially controlled with current technology, and a range of droplet sized is always produced. The largest droplets fall out relatively quickly, while smaller droplets are dispersed more by turbulence and are carried farther. If droplets are too large, target coverage may be insufficient. Also, some dispersion of the spray is desirable to spread the swath more evenly and to penetrate target foliage adequately. Spreading of the swath is predominantly downwind, and it allows swaths to overlap so that a more uniform coverage can be attained. However, if the spray is carried too far downwind, it is hard to control and may pose a hazard. Such uncontrolled transport of spray into nontarget ares is commonly called spray drift. The portion of the spray that is carried farthest is composed of the smallest droplets or insecticide in vapor phase that has evaporated either from airborne droplets or later from deposited droplets. Consequently, formulations, spray equipment, and conditions have been designed to minimize the production of very small droplets.

In Region 6, rotary atomizers are normally used for insecticide spraying, and formulations are applied in a total volume of 0.5 gallon per acre. The formulation (described in an earlier section) may use a mineral oil carrier (for some B.t. formulations) or a diesel oil carrier (for carbaryl applications) or water (for malathion or acephate formulations). The median droplet sizes produced by the rotary atomizers range from approximately 100 to 150 microns, and the range of droplet sizes is well controlled subject to the limitations of available technology. Figure 3-1 shows the distribution of droplet diameters measured by Yates, Akesson, and Cowden (1984) for a Micronair AU 5000 spray in a wind tunnel at 100 mph.

The distance that spray is transported also depends on meteorological conditions and the density of intercepting vegetation. Drift is controlled by making applications only when wind speed are less than 8 mph. Conditions favoring evaporation are avoided by making applications only when relative humidity is greater than 50 percent and the air temperature is less than 70°F. The forest canopy is typically dense enough to intercept most of the applied material, with typical tree heights of 75 to 100 feet, and a significant understory.

Topography also can exert a relatively large effect on the degree of spray drift. Spruce budworm spraying is typically carried out in mountainous terrain, although relatively level lands also are sprayed. Yates, Akesson, and Cowden (1978) have shown that applications in mountainous terrain under some conditions can produce drift deposition as much as 10 times as high as on flat land.

For the purposes of this risk assessment, the study by Yates et al. (1978) has been used as a basis for calculating spray drift. This study was used because it investigated realistic spruce budworm spraying conditions, similar to those existing in Region 6, yet it represents a case that is conducive to spray drift in terms of topography and meteorology. Thus, the drift estimates used for the risk assessment are conservative and unlikely to underestimate drift.

Data from three of the trials reported by Yates et al. (1978) were used. The Forest Service conducted these trials on the Helena National Forest in

Montana. Orthene (acephate) was applied to two plots, and Dylox 4 in oil was applied to the third. All of the applications were made by a Bell 205A helicopter using Beecomist Model 350 spray heads. The aircraft flew at 90 mph. All of drift measurements were taken at the bottom of canyons below the treated areas during early morning hours when downslope winds occurred. The deposition measured on mylar sheets indicated that an average of 19 percent of the application rate was deposited at 500 feet from the plot (the range was 6.2 to 40 percent. This is equivalent to about 214 grams per hectare (g/ha) for a 1,120 g/ha (1 lb/acre) application rate. At 100 feet from the plot, the data indicate (by extrapolation) that an average of 59 percent of the application rate was deposited (ranging from 52 to 70 percent). This is about 664 g/ha at an 1,120 g/ha (1 lb/acre) application rate.

Yates et al. (1978) also measured concentrations of airborne droplets in these same tests by drawing air through glass fiber filters. When these observations were compared with the results of tests conducted on flat land, it was found that the airborne concentrations were significantly lower under the mountainous conditions. Consequently, again following a conservative approach, the results for the flat land test (using D6-46 nozzles) were used to estimate exposures for this risk assessment.

Based on exposures given by spell et al. (1978), mean insecticide concentrations in air were calculated for the duration of the field tests (2 to 3 hours). Estimated concentrations were 9.16×10^{-3} mg/m^3 at 1000 feet downwind and 4.58×10^{-3} at 500 feet downwind.

Runoff Modeling

A second mode of potential human and environmental exposure is to insecticides carried in rainwater runoff from sprayed areas. Aerially applied pesticides settle onto forest, vegetation, soils, and water. Following application, pesticide concentrations decrease as the chemicals are degraded or adsorbed to organic matter in forest soils. Chemical properties of the pesticide, climatic conditions and, to a lesser extent, the mode and rate of pesticide application, as well as vegetation and soils determine the fate of applied pesticides. Carbamate and organophosphate insecticides (which include acephate and malathion) are known to be relatively nonpersistent in the forest floor and soil (USDA, 1980). The half-life of an insecticide is a parameter that describes the time it takes for concentrations (usually in soils) to be reduced by 50 percent as a result of all decay and degradation processes. Soil half-lives are calculated from decay constants (Table 3.1B) and range from 6.5 to 0.4 days.

When rain falls on a forested area just recently sprayed, the amount of a pesticide that enters a stream from surface runoff depends on the distance from the treated area to the stream, infiltration and sorptive characteristics of the soil, and the rate of runoff. The persistence of the insecticide after it has entered the water is primarily a function of its chemical properties. Insecticide concentrations are reduced by volatilization, sorption, hydrolysis, photolysis, degradation, and dilution.

Conceptual Model

Insecticide concentrations should decline rapidly because of decay and degradation, and Forest Service protocol for pesticide application restricts spraying if a storm is predicted within 6 hours of application. However, if an unexpected large storm occurs in an area that has just been sprayed, a relatively high proportion of the pesticides may be washed into streams and transported into downstream reservoirs. This analysis examines the consequences of such an event on a typical watershed in the budworm infestation area. The analysis incorporates site-specific soils and climatic data and a hypothetical insecticide application scenario.

The Dalles Watgershed Management Unit is approximately 41 square miles (26,000 acres) in area. No more than 5,000 acres in a single watershed are sprayed in a single day, which--in this case--represents approximately 19 percent of the total watershed. In assessing the potential for contamination of water resources, a worst case scenario was developed that would produce a high negative impact on the water quality in the watershed.

Spruce budworm eradication efforts normally take place during the mid-summer months. A worst case scenario assumed that three separate 5,000-acere subareas (A, B, and C in figure 3.2) are sprayed with pesticides on 3 consecutive days in July; and on the fourth day, a large rainfall occurs. The concentration of pesticides in the runoff from each separate subarea was calculated, and a mass balance equation was used to estimate pesticide concentrations in a downstream reservoir that receives the combined runoff. Using conservative assumptions about pesticide decay rates and dilution, a reasonable, conservative estimate of pesticide concentration was produced in runoff and in water that leaches into the subsurface.

Runoff Model

The Simulator for Water Resources in Rural Basins (SWRRB) model was developed (Williams et al., 1985) to predict how management decisions affect water and sediment yields on ungaged rural water basins up to several thousand square kilometers in area. The SWRRB model was constructed by modifying the CREAMS model (Chemicals, Runoff and Erosion from Agricultural Management Systems) to allow simultaneous predictions on several sub-basins. A version of SWRRB, called the Pesticide Runoff Simulator, was developed by the Office of Pesticides and Toxic Substances of the U.S. Environmental Protection Agency (Carsel, 1980) specifically to simulate pesticides in nonpoint source runoff, and Version 3 of this model was used in all of the following simulations. SWRRB has been found to realistically simulate water and sediment yield in a wide range of conditions (Arnold and Williams, 1987). Honeycutt and Ballantine (1983) used SWRRB to estimate pesticide concentrations in nonpoint runoff and performed a sensitivity analysis of the model. They found SWRRB to be sensitive to rainfall intensity and pesticide parameters.

SWRRB contains the following four major components: weather, hydrology, erosion, and pesticide.

Weather Component. In contrast to more recent versions of SWRRB, EPA Version 3 requires daily rainfall, monthly temperature, and solar radiation as input. The model simulates daily air temperature and solar radiation based on a normal distribution.

Hydrology Component. Surface runoff is predicted using the Soil Conservation Service (SCS) curve number equation. Because the curve number (CN) varies depending on the amount of moisture in the soil, SWRRB uses a soil moisture accounting procedure to estimate a new CN for each storm. Evapotranspiration is computed with Ritchie's mode using predicted daily temperature and solar radiation. Percolation through the root zone is computed with a storage routing technique that predicts flow through each layer.

Erosion Component. Sediment yield is calculated for each subarea using the Modified Universal Soil Loss equation. This equation predicts average soil loss based on soil type, agricultural management practices, and topography.

Pesticide Component. The pesticide component of SWRRB takes into account physical processes that affect pesticide concentrations such as adsorption to soil surfaces and sediments, degradation processes, and application efficiency. Pesticide concentrations are estimated for nonpoint runoff and water leached below the top centimeter.

Model Input

SWRRB requires two sets of data as input: a river basin set and a pesticide set. The river basin data set contains information required for the weather, hydrology, and erosion components of the model. Several subareas can be defined within a watershed; however, pesticide concentrations are estimated only for the total drainage basin. Each pesticide requires a separate data set.

Because interest was in insecticide concentrations in runoff from each of the subareas as well as in the reservoir, each of the 5,000-acre subareas was modeled as a separate basin, and insecticide concentrations in the combined runoff were determined by mass-balance calculations. A schematic representation of the watershed is shown in Figure 3-2. River basin characteristics used in modeling were largely the same for all subareas, differing only in soil properties. Insecticide data sets constructed for each subarea contain the different application times: subarea A was treated first, followed by subarea B and subarea C.

Three predominant soil types were identified from a soil survey of the Mt. Hood area (USDE, 1979), and each subarea was assigned a different soil type and corresponding values of the soil parameters. Representative values of these parameters are given in table 3-5. Site-specific data were obtained whenever possible from Forest Service scientists at Mt. Hood and from Engineering Handbook (USDA, 1972), An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook) (USDA, 1980), and the CREAMS Users Manual (Knisel, 1980). Conservative values of soil and pesticide parameters were used when available.

The maximum precipitation of the 100-year, half-hour storm was estimated to be 3.67 inches (Lowrey, 1988). Because the model has a daily rather than hourly time step, this value was used as input on a single day after a 1-week dry period to represent the large rainfall event. Insecticides were applied to the forest subareas on each of the 3 days prior to the storm. Insecticide parameters and application rates are given in Table 3-6. Application

efficiency was assumed to be 100 percent, in line with the worst case scenario. A more realistic value for aerially applied pesticides between 40 and 60 percent (Knisel, 1980).

Results

Insecticide concentrations estimated by SWRRB are given table 3-7. The combined peak runoff rate from the subareas (1,550 ft^3/s) corresponds approximately to the measured inflow to the Crow Creek Reservoir resulting from the 100-year event that occurred in 1974 (1,471 ft^3/s) (Dennee, 1988). In addition, runoff volume does not vary significantly betweem the three subareas (45.0 to 45.4 acre-foot).

Concentrations in the runoff from subareas (table 3-7) are estimated directly by SWRRB and vary roughly from 10 to 200 ppb. In all cases, contaminated runoff was derived from the one large storm. Between 97 and 99 percent of the applied malathion decayed on the ground or foliage, compared with 40 to 63 percent of the carbaryl.

Concentrations of insecticides in the combined runoff from the three subareas and in the reservoir were calculated by mass balance with the following simplifying conservative assumptions:

- Pesticide concentrations in runoff are constant throughout the runoff event.
- Runoff is not diluted by uncontaminated rainfall, groundwater, interflow, or runoff from untreated portions of the watershed.
- All water in stream channels is derived from runoff.
- Complete mixing occurs in streams and in surface impoundments.
- Direct input of pesticides as a result of spraying surface water is negligible.

These conservative assumptions tend to overestimate insecticide concentrations. In general, concentrations in the reservoir resulting from inflow of runoff from treated areas range roughly from 1 to 20 ppb.

Modeling of Leaching

Results (table 3-8) show that two of the three insecticides have the potential to leach below surface soils. An estimated 30 to 60 percent of acephate and 50 to 70percent of carbaryl that are applied leach below the top 1 centimeter (cm.) of soil, compared with approximately 1 percent of malathion. This is a function of the greater tendency of malathion to decay in soils (table 3-6). Estimated concentrations of acephate and carbaryl in the root zone are all less than 100 ppb. Pesticide concentrations in water in the plant root zone and in water that migrates below the plant root zone will be reduced by dilution and decay with time.

Leaching of pesticides is a slow process in highly organic forest soils and only small amounts of chemical will move short distances (USDA, 1980). Studies

have shown that degradation of acephate in water is accelerated because of breakdown by aquatic vegetation and microorganisms, which reduce concentrations to a negligible level after 1 to 9 days (USDA, 1980).

irrigation Water Modeling

Humans may be exposed to insecticides by consumptions of crops that are irrigated by water contaminated insecticides. This scenario can be divided into three separate steps: contamination of water resources and application of the water to the crops, uptake of the insecticide by the plant, and consumption of the crops by humans.

Insecticides may be transported into surface waters used for irrigation by washing off plant surfaces into streams and lakes, by rainfall, and by drifting onto open bodies of water such as large rivers or reservoirs. The amount of insecticide that runs off a treated area depends on the intensity and duration of rainfall, time between application of the insecticide and the rainfall event, type of ground cover, soil, land slope and properties of the insecticide (Weber et al., 1980). A reservoir that has accumulated insecticides from drift may release the contaminated water for irrigation before degradation processes can reduce insecticide concentrations. Processes that reduce the concentrations and mobility of insecticides include:

- o Sorption
- o Volatilization
- o Degradation process: hydrolysis, photolysis, microbialdegradation.

Some irrigation techniques, for example sprinkler systems, will aerate the water more than others and result in increased volatilization of the insecticide and reduced levels in the applied irrigation water. Thus, insecticide concentrations are likely to be higher in water applied using flood or gravity type irrigations systems.

The Crow Creek Reservoir of the Dalles Watershed Management Unit, located in the northeast of the Mt. Hood Forest Service Region, is used as an example case to assess the risk of insecticide exposure to humans from irrigation water.

Insecticide Concentrations in Irrigation Water

Insecticides will not be sprayed directly into irrigated fields, but reservoirs used for irrigation water may receive insecticide residue via aerial drift or runoff. Plants that are subsequently irrigated with this water may accumulate insecticides, and result in exposure to humans that consume them.

Water in the Crow Creek Reservoir is all allocated to the city of The Dalles, with the exception of 2 acres of irrigated land (Toll, 1988), and is piped directly from the outlet of the reservoir to a Water Treatment Facility. Although in this specific case there is a negligible risk from consuming crops that have been irrigated by contaminated water, this example can be used as a conceptual model for the case where such a possibility does exist. It is assumed that water from the reservoir is used for irrigated agriculture.

The Crow Creek Reservoir has a mean surface area of approximately 31 acres, and a mean volume of 616 acre-ft, based on an average from 1986 to 1987 (Toll, 1988). Due to the configuration of the reservoir, its surface area does not change significantly throughout the year; however, the volume of the reservoir may fluctuate by 200 to 300 acre-ft (Toll, 1988).

Insecticides are applied to the area surrounding the reservoir leaving a buffer zone of 100 ft between the edge of the treated area and the edge of the lake. The drift rates of insecticide concentrations were measured on the ground 100 and 500 feet away from the treated land surface and were determined to be 664 and 214 (g/ha per lb/acre) respectively.

The shape of the lake approximates a rectangle about two times as wide (north to south) as it is long (east to west). If a linear relationship is assumed between concentration and distance from application, and drift rates and application rates are known (see Table 3-9), the mass input of insecticide as a function of distance, and the average mass input (mg/sq ft) can be calculated.

Based on the calculated mass input gradient of insecticide, concentrations derived from drift are negligible at a distance of 590 ft or more from the edge of the lake on the side that the insecticide is applied. The affected surface areas of the lake is 969,370 sq ft, or approximately 70 percent of the total surface area of the lake.

Insecticide drift calculations take into account the volatilization of pesticide compounds. Neglecting decay processes that decrease insecticide concentrations, the concentration of compounds in the reservoir can be estimated by:

Cwater = (MI)*(ASA)/(V)

where:

Cwater = concentration of insecticide in water [mg/l]
MI = average mass input of pesticide [mg/sq ft]
ASA = affected surface area of reservoir [sq ft]
V = Volume of water in reservoir [l]

Estimated insecticide concentrations in the reservoir water are given in Table 3-10.

Insecticide Concentrations in Irrigated Crops

The concentrations of insecticides in irrigated crops are calculated based on relationships between the soil, water, insecticide, and crop plants. The following assumptions were used to simplify calculations:

- Chemical equilibrium is rapidly established between insecticide concentrations in the soil and the soil water.
- Insecticide concentrations in the soil water can be considered constant over the exposure period of the plant, which is related to the half-life of the insecticide.

- Chemical equilibrium exists between insecticide concentrations in all plant parts

- Insecticide concentrations in plant material do not decrease after exposure ceases.

- Soil organic carbon content is spatially variable, but can be approximated by an average value.

- Effects of volatilization on the aqueous concentration of the insecticide are less than those due to sorption, and can be initially neglected.

- Calculated insecticide concentrations that neglect degradation processes (photolysis, hydrolysis, and microbial degradation) yield values that can be used as an upper bound.

To simplify the calculations the time dependence of aqueous insecticide concentrations, which are both volatilized and degraded after application is neglected. the effect of the latter two assumptions listed above is to overestimate concentration of the insecticide both in aqueous phase, and in the plant. An estimate of time-dependent insecticide concentrations can be obtained using a model such as GLEAMS (Leonard et al (1987), or the PRZM (Carsel et al., 1984) model which take into account degradation and volatilization of the insecticide using empirically derived decay constants.

Bioconcentration Factor (B_v)

The bioconcentration of organic compounds by vegetation is traditionally measured by a biioconcentration factor (B_v) which is defined as the ratio of the concentration of the chemical in plant tissue to the concentration of the chemical in soil.

A study by Travis and Arms (1988) determined an empirical relationship between bioconcentration factors for organic chemicals in vegetation, and the octanol-water partition coefficient (K_{ow}) of the chemical. A geometric mean regression of these parameters for 29 chemicals used on vegetation determined that the relationship is:

$$\log B_v = 1.588 - 0.78 \log K_{ow} \qquad (1)$$

The correlation coefficient (r) of these data is 0.73. The inverse relationship between B_v and K_{ow} indicates the dependance of insecticide concentration in the plant on uptake of the soluble fraction of the insecticide from soil water in the plant's root zone. Aqueous solubility is inversely proportional to K_{ow}. The concentration of the insecticide in the soil water was assumed to be constant over the period of the experiment (Arms, 1988).

Although the study by Travis and Arms did not include the specific insecticides under consideration at this site, they included a variety of classifications of insecticides. Therefore, this empirical formula (equation 1) can be used to calculate bioconcentration factors of insecticides for this study (Arms, 1988):

Compound	K_{ow}	B_v

Acephate	0.0428	239
Carbaryl	651	0.916
Malathion	776	0.827
Diesel (octane)	10,000	0.189

Partitioning of insecticides between soil and water phases.

Acephate, carbaryl, and malathion can be expected to sorb to organic matter in the soil to varying degrees depending to a large extent on the hydrophobicity of the insecticide. Sorption effects can be estimated by taking into account the percent organic matter in the soil, the concentration of the insecticide in water applied to the soil, and the organic carbon distribution coefficient (K_{oc}) of the soil.

The organic carbon partition coefficient (K_{oc}) describes the equilibrium relationship between the insecticide solution and the sorbed phase. K_{oc} is calculated from the distribution coefficient (Kd) of the insecticide, normalized for the fraction of organic carbon (OC) in the soil or:

$$K_{oc} = (Kd)/(OC)$$

Experimental values of K_{oc} and Kd are given in Appendix A.

Soils found in the Mt. Hood Forest Service Region are derived mainly from weathered volcanic rocks. The percentage of organic matter in The Dalles Watershed soils estimated from mapped soils units ranges from 0.53 to 5.32, with an average of approximately 3 (USDA, 1979).

Insecticide Concentrations in Irrigated Crops

The concentration of insecticides in vegetation can be estimated from the concentration of the insecticide in the soil, and the bioconcentration rate of the insecticide, or:

$$Cplant = (Cwater)*(K_{oc})*(OC)*(B_v) \qquad (2)$$

where:

Cplant = concentration in the plant [mg/kg]

Cwater = concentration in the water [mg/l]

K_{oc} = organic carbon distribution coefficient [l/kg soil]

OC = fraction organic carbon of soil

B_v = bioconcentration factor [(mg/kg plant)/(mg/kg soil)]

Estimated concentrations of insecticides in plants are given in Table 3-11.

EXPOSURE CALCULATIONS FOR HUMANS

Results of the environmental transport and fate modeling give estimates of insecticide concentrations in environmental components that may lead to human exposure. Those exposures are estimated in this analysis using scenarios that represent likely exposure routes and persons at risk. Exposures are assumed to occur both in routine insecticide spraying operations and in accidents. This section describes the calculation of human exposures for both routine and accident scenarios. The results of the human exposure analysis are presented later in this chapter. The calculated exposures represent a full range of the kinds and magnitude of exposure that could occur, while restricting the calculations to a reasonable number of cases. To avoid underestimating exposures, many parameters and assumptions were chosen so that calculated exposures would err on the high side. The exposure scenarios assume that some required operational procedures are disregarded.

Some of the exposures are described as routine, meaning that they could occur under routine circumstances, but only if conditions are conducive to exposure. If operational procedures are complied with, average exposure would be lower. Routine exposures were further divided into typical and worst case exposures. Typical exposures throughout the analysis were based on typical application rates and spray drift at 500 feet offsite from a treated area. Worst case exposures were based on worst case application rates and drift at 100 feet offsite.

Exposures have also been calculated for accidental situations that range from those likely to occur occasionally, for example, the direct spraying of a worker, to those that are very unlikely, for example, jettison of a full load of insecticide into drinking water source. The kinds of exposures calculated for humans are listed in Table 3-12.

Exposures to Workers

Exposures to workers from the three insecticides, from B.t., diesel oil, kerosene, and from the combined petroleum distillates, are shown in Tables 3-13 to 3-19.

Pilots and Mixer/Loaders

Exposures to pilots and mixer/loaders were estimated from a field monitoring study by Atallah et al. (1982). This study has been used to estimate worker exposures by the Exposure Assessment Branch of EPA (Reinert and Severn, 1985). In this study, respiratory exposures were measured with air sampling tubes and a calibrated air sampler attached at the waist. Dermal exposures were measured from hand rinses and denim patches attached to the face, the back of the neck, the front of the neck, the "V" of the upper chest, and the forearms. For this analysis the dermal and respiratory exposures (reported as ug/8-hour workday) in this study were averaged for each of the worker categories and adjusted to an average application rate of 1 lb/acre. The average dermal exposures were 3,009 ug/8 hours for pilots and 6,774 ug/8 hours for mix/loaders.

Typical doses to workers for the spruce budworm project were calculated using the average adjusted exposure values described above and the application rate and dermal penetration rate of each chemical. The exposures also were adjusted for the number of hours worked per day. Workers were assumed to wear no

special protective clothing and have a body weight of 70 kg (about 150 lbs). For worst case exposures the upper 95-percent confidence limit from the Atallah et al. (1982) study was used. Worst case exposures also included the high application rates.

Exposures on sprayed sites and those resulting from accidental direct spraying were based on the full planned application rates in pounds per acre. Exposures at 100 and 500 feet from the spray site are based on the aerial spray drift model described previously. It was assumed that the wind blows directly from the spray site and that the terrain is steep. Under actual conditions, spray drift should be less than estimated in this analysis. Operational procedures require spraying when winds are less than 8 miles per hour and under other conditions that minimize drift.

Dermal penetration of malathion was estimated to be 7 percent for forearm skin, based on a study of human subjects (National Library of Medicine, 1986). Dermal penetration of carbaryl was estimated to be 10 percent, based on an analysis of field exposure data (USDA, 1985). Dermal penetration of diesel and petroleum oils was estimated to be 25 percent. Dermal penetration of acephate was estimated to be 10 percent, based on a comparison of oral and dermal LD_{50} values (Curley and Donohue, 1986). These penetration estimates were expressed as fixed percentages based on dermal exposure studies that occurred over extended periods of time. In fact, dermal penetration is time dependent. If a person washes within the first few hours after exposure, penetration will actually be less than assumed in analysis. Penetration through clothing was assumed to be 30 percent as great as through bare skin, based on work by Newton and Norris (1981) on phenoxy herbicides.

Dermal doses to workers from accidental spills were calculated assuming that one-half liter of insecticide concentrate (or mix for acephate, which is used as a powder) is retained--90 percent on the worker's clothing and 10 percent on the skin. This amount of liquid is sufficient to wet most of the worker's body.

Observers

Observers near the spray operation were assumed to receive does through inhalation and dermal absorption.

Dermal exposures were calculated for 2 square feet of exposed skin. The dermal penetration rates and drift deposition values that were described previously were used.

Inhalation exposure was calculated based on air sampler data collected during the field trials by Yates et al. (1978) described earlier in the spray draft modeling section. The worker's breathing rate was assumed to be 21.7 liters per minute (1.3 cubic meters per hour), which represents an average for an adult during moderate activity (EPA, 1981, as cited in EPA, 1986). Inhaled doses were calculated assuming that spray droplets are inspired by people with the same efficiency as by air samplers. One-hundred percent of the inspired droplets were assumed to be retained and absorbed. Doses were adjusted to reflect the typical and worst case number of hours a worker would be exposed.

Card Checkers and entomology Efficacy Team Members

Card checkers and members of the entomology efficacy team may receive doses from contact with sprayed vegetation. They are not expected to receive a dose by way of inhalation exposure.

Indirect dermal exposure as a result of contact with foliage with surface residues of drifted insecticide was calculated by using the 'unified field model" of Popendorf and Leffingwell (1982) and Popendorf (1985). This model was developed to estimate the possible doses and effects of insecticides on agricultural workers. The model takes into account:

- The residue on foliage at any time after application
- A crop-specific residue transfer coefficient (cm^2/hr)
- The exposure period in hours
- The dermal penetration rate for each insecticide and the body mass of a human (70 kg)

The residue transfer coefficient has been determined for a few agricultural situation. The value of 1,600 cm^2/hour for this coefficient was used in this analysis to estimate doses to card checkers and members of the entomology efficacy team that may contact treated foliage. This value, derived from data collected from grape harvesting (Popendorf, 1985), represents a relatively high exposure situation. People engaged in activities involving less foliage contact can be expected to receive doses that are considerably less. People who contacted foliage after the initial application also receive reduced doses because of degradation of the insecticides.

The analysis included degradation of insecticide residues between the time of application and the time the worker entered the treated area. The number of hours exposed per day also was included in the dose estimates.

B.t Exposure Estimation

Exposures to B.t. were calculated similarly to the chemicals, with the following changes:

- The application rates of 12 and 16 BIU/acre fro typical and worst case, respectively, were converted to equivalent pounds per acre assuming 7.26 BIU per pound, as for Dipel powder. The resulting rates are 1.65 and 2.2 lbs/acre, respectively.
- Dermal exposures to B.t. were not calculated.
- B.t. was assumed not to accumulate in meat or fish.
- B.t. was assumed not to degrade or reproduce during the period between treatment and exposure.

Overestimation of Worker Doses

As described above, this risk assessment estimates two separate dose levels for each category of worker in routine operations, a typical dose and a worst case dose. The typical dose is an estimate of the average dose a worker should receive on a typical day during normal treatment operations. The typical dose is based on combining average nominal doses from field studies with scenario conditions that are typical for Forest Service operations in the Pacific Northwest.

However, the typical dose estimates are higher than those that would occur in actual operations. The doses are based on field study doses of applicators who wore no special protective clothing or devices. In many of the proposed Forest Service operations, workers will probably wear protective gear.

used for extrapolation are not the average dose seen but the dose at the upper limit of the 95-percent confidence interval. This means that there is only 1 chance in 40 that a worker in the same field operation under the same conditions of terrain, weather, and equipment would receive a dose higher than the specified dose. Second, when this upper limit dose is combined with the assumptions of highest application rate for dose for dose extrapolation, extremely high doses are estimated that are unlikely to occur under true operational conditions. The probability of these events occurring at the same time is low.

In addition, the field study may also take into account normal operational errors, such as the following:

- o Errors of measurement during manufacturing and formulation
- o Errors of measurement during field mixing
- o Excessive swath overlap during application

Exposures to Members of the Public

Exposure to members of the public from the three insecticides, B.t., diesel oil, kerosene, and other petroleum distillates are shown in Tables 3-13 to 3-19.

Dermal Exposures

Dermal doses resulting from incidental contact with foliage, represented in the scenarios by vegetation contact for the hiker, were estimated by another method. Lavy et al. (1980 measured the level of 2,4,5-T herbicide on cloth patch samplers attached to a person who walked through a treated forest area. The residues were less than the detection limit of 0.01 mg per 100 cm^2 patch, but in this analysis a conservative assumption was made that residues were at the detection limit. The area of clothing contacting foliage was assumed to be 40 percent of the total human surface area, and 10 percent of the total area was assumed to be bare skin contacting foliage. The same dermal penetration rates discussed previously were applied to bare skin, but the penetration through clothing was assumed to be 30 percent over a 6-hour period, based on work by Newton and Norris (1981).

Dermal exposures were estimated for a 70-kg adult wearing short sleeves and trousers, assuming that 2 square feet of skin is covered with insecticide at the full application rate or drift deposition rate. In fact, this procedure is

likely to further overestimate exposures because spray droplets, depending on their size and the wind velocity, tend to be carried around obstructions rather than landing on their surface (see Golovin and Putnam, 1962). Very small droplets, typical of ULV sprays, are the most likely to be carried around obstructions.

Dermal exposures for accidents were calculated assuming an adult is directly sprayed at the maximum application rate and that 2 square feet of skin are uncovered. Calculations were also done for a child weighing 20 kilograms. The dose to the child was adjusted relative to the adult using the body surface area ratio and body weight ratio.

Inhalation Exposures

Exposures by way of inhalation of insecticide vapors or droplets were calculated for members of the public based on the results of studies by Yates et al. (1978) described previously under spray draft modeling. Doses were calculated assuming a person respires at a rate of 1.3 M^3 of air/hour and is exposed for 2 hours.

Oral Exposures

All oral exposures were calculated assuming that do degradation occurs between spraying and eating or drinking. Label directions require preharvest waiting periods for many crops, so the exposures calculated here apply only if the label is ignored.

Residues on Plants

Insecticide residues on plants on treated sites were estimated based on factors reported by Hoerger and Kenaga (1972). These factors were derived from a large number of studies, and they allow prediction of residues in parts per million (ppm) based on the application rate in pounds per acre. These residue estimates were calculated assuming no insecticide degradation, so they apply to conditions immediately after application. After the Hoerger and Kenaga (1972) study,the plants were classified into broad groups based on vegetative yield, surface-to-mass ratio, and plant interception factors. The residues estimated for each type of plant are intended to represent realistic yet relatively high estimates.

Offsite plant residues were calculated first for grasses, based on the spray drift data discussed in the previous section, and by using a regression equation given in Yates et al. (1978) to relate spray deposition on young wheat plants to that on sampling devices. The deposition was then estimated for other plant groups including berries and legumes (peas or beans) by using the same relative factors given by Hoerger and Kenaga (1972), assuming that deposition on young wheat was approximately the same as deposition on range grass.

Insecticide doses to individuals were calculated assuming that they eat 500 grams (1.1 pounds) of contaminated berries or legumes at 500 and 100 feet offsite.

Doses were calculated for accidental exposure assuming legumes received direct spray at the worst case application rate.

Residues in Fish

Typical oral doses from eating fish were calculated assuming that the fish is taken from a body of water (pond) 2 feet deep, receiving drift at 500 feet downwind of a sprayed area. The fish was assumed to have residues resulting from equilibration with the water at a bioconcentration factor of 1 for malathion and carbaryl, 13 for diesel oil, and 10 for acephate. It was assumed that 0.5 kg of the fish was eaten. Worst case exposures were estimated using high application rates and drift 100 feet offsite.

Residues in Game Animals

Insecticide residues were calculated for 150-pound deer. The entire body surface area of the animal was assumed to be exposed to spray drift. Forty present of the body surface as assumed to contact vegetation and thereby gain an additional average dermal residue level equal to that on the vegetation. Penetration of the insecticides through animal skin was assumed to be the same as through human skin.

The deer was assumed to get an oral dose both by grooming and in its diet. The dose from grooming was assumed to amount to 29 percent of the nonabsorbed dermal dose. The deer diet was assumed to consist of 2.45 kilograms of forage plants and 4 liters of water per day, both containing the insecticide.

The concentration of insecticide in game meat was calculated by summing the animal's doses from both the dermal and oral routes of exposure and by assuming that 10 percent of that total dose was retained in the meat of the animal. This is similar to the method used in the exposure analysis of USDA (1984). Insecticide doses to humans were calculated by assuming that they eat 500 g of deer meat per day.

Insecticide and B.t. Residues in Water

Doses were calculated for humans drinking contaminated water from several contaminated sources. A shallow (2-feet deep) source was assumed to receive drift at 500 feet downwind of the sprayed area. No degradation or adsorption to sediments was assumed to occur before drinking 2 liters. The concentrations in the water were calculated as simple dilutions. For worst case exposures the high application rates were used and the body of water was assumed to bed 100 feet offsite. The actual residues in water would be less under more favorable spray conditions, at greater distances, or with deeper water bodies. Dilution or degradation also would decrease residues.

Accidental drinking water exposure also was calculated by dilution for a spill from an aircraft load of 200 gallons into a 1-acre pond.

An example calculation for acephate concentration in water is given below. The concentration in a 24-inch (0.61 meters) deep body of water per pound applied per acre at 500 feet from the sprayed area is:

mg 3

$\frac{214g}{ha} \times \frac{1,000}{10,000} g 2x \quad \frac{1}{0.61 \text{ meters}} \quad \frac{M}{1,000 \text{ liters}} \; 0.035$ mg/l or ppm

$\underline{m}$

ha

The concentration of acephate is adjusted for the typical pounds per acre applied:

$$0.035 \text{ ppm} \times 10 = 0.18 \text{ ppm}$$

The concentration in the fish is based on the bioconcentration factor of acephate (10x):

$$0.018 \text{ ppm} \times 10 = 0.18 \text{ ppm or mg/kg}$$

The dose to a 70kg human based on consumption of 0.5 kg of fish is:

$$\frac{(0.18 \text{ mg/kg} \times .5 \text{ kg})}{70 \text{ kg}} = 0.0013 \text{ mg/kg}$$

Cumulative Exposures

Cumulative exposures were calculated for members of the public who may receive exposures from a number of different pathways. Cumulative exposures were calculated for fishermen assuming they receive doses from drinking 2 liters of water, eating 0.5 kg of fish, and having incidental contact with sprayed vegetation. Cumulative exposures were calculated for hunters assuming they receive doses from drinking 2 liters, of water, eating 0.5 kg of deer meat, eating 0.5 killigrams of berries, and contacting sprayed vegetation.

Exposure From Consumption of Runoff Contaminated Water

Humans may be directly exposed to pesticides by consumption of contaminated water. Pesticides are primarily transported into surface waters via runoff from treated areas that flows into streams and lakes.

The Crow Creek Reservoir of The Dalles Watershed Management Unit located in the northeast of the Mt. hood Forest Service Region, receives runoff from surrounding forested areas that may be contaminated as a result of pesticide applications in the watershed. All water in the Crow Creek Reservoir is allocated to the city of The Dalles, with the exception of 2 acres of irrigated land (Toll, 1988), and is piped directly from the outlet of the reservoir to a water treatment facility.

Humans are exposed to pesticides if they drink water that has been contaminated. Worst case pesticide concentrations in reservoir water were estimated in the runoff study and are presented in Table 3-7. If a 70-kg person (Hw) is assumed to drink 2 liters of water per day (Hc), the dose of each pesticide to humans can be calculated using the following equation.

$$Hd = (Hc)*(Cwater)/(Hw) \qquad (1)$$

where:

Hd = Dose (concentration) in humans [mg/kg/day]
Hc = Human consumption rate of water [l day]
Cwater = Concentration in the water [mg/l]
Hw = Body weight [kg]

Human Exposure from Consumption of Crops

Humans are exposed to insecticides if they eat crops that have been grown with contaminated irrigation water. Assuming that the insecticide is distributed uniformly throughout plant parts, and is not degraded by cooking or other forms of food preparation, daily human doses are estimated as:

$$Hd = (hc)*(Cplant)/(Hw) \qquad (3)$$

where:

Hd = Dose (Concentration) in humans [mg/kg/day]
Hc = Human consumption rate of vegetables [kg/day]
Cplant = Concentration in the plant [mg/kg]
Hw = Body weight [kg]

Overestimation of Public Exposures

The doses estimated for members of the general public are overestimates for a number of reasons. The smaller spray particles in offsite drift tend to move around rather than land on curved surfaces and therefore would have less of a tendency to adhere to a human's body. Second, no degradation of the insecticide is assumed to occur nor is the insecticide assumed to bind with any material, such as vegetation, so as to become biologically unavailable to humans. This would be an important factor in diminishing doses that may occur from any activity involving contact with treated vegetation.

The routine-worst case dose levels to the public can be considered the highest possible doses for routine spray operations because the doses are calculated in scenarios that combine unlikely factors and events, including highest application rate and smallest buffer zone. No member of the public should get a dose that is any higher than the doses estimated in the routine-worst case scenarios except in the case of an accident.

Estimation of Lifetime Doses to Workers and the Public

Doses used in the cancer risk analysis were derived by combining available information on the number of days per year an individual worker may spray an insecticide using a particular application method and estimates of the expected daily dose and the number of years of employment. Expected daily doses were calculated assuming that the worst case dose is experienced 10 percent of the time and the realistic dose 90 percent of the time, in all routine scenarios. Workers are assumed to be emloyed in pesticide application for 30 years. Average numbers of exposures per lifetime were used with expected daily doses for each scenario to derive realistic lifetime doses. Extreme lifetime doses were derived by multiplying expected daily dose levels estimated in worker scenarios by estimates of the highest number of days a worker is likely to be engaged in the particular type of application method.

Lifetime exposures to the public for the insecticides were derived by assuming 10 exposures per lifetime in each of the public exposure scenarios. Cancer risks for accidents were based on a single exposure in a lifetime.

Effect of Body Size on Exposure

All doses estimated in the exposure analysis were calculated for a representative 70-kg person. This weight was chosen to represent an adult of average weight.

Doses for a smaller person would be more in terms of mg milligram per kilogram of body weight. For example, a 70-kg person would receive approximately 2.3 times more insecticide than a 20-kg person by dermal exposure, because the surface area of each is different. A 70-kg person also would receive on average about 2.3 times more insecticide by dietary exposure routes, because both body surface area and metabolism are approximately proportional to body weight raised to the 2/3 power:

$$\frac{(70)^{2/3}}{(20)^{2/3}} = 2.3$$

A 70-kg person also has a body weight greater than a 20-kg person, by a greater factor:

$$\frac{70}{20} = 3.5$$

The combined effect of these two factors is that a 20-kg person will receive a dose in milligrams per kilograms that is about 1.5 times greater than for a 70-kg person.

Time Dependence of Dermal Exposure Resulting from Vegetation Contact

Insecticide residues on plant surfaces decline over time as a result of absorption by the plant, degradation, volatilization, and washing by rainfall. After insecticide sprays dry on plant surfaces, they cannot be completely rubbed off because they bind to the plant surface materials. Consequently, persons entering a treated area a short time after spraying are likely to receive dermal doses much smaller than the conservative doses calculated in this analysis. However specific data were not available for the insecticides regarding persistence on plant surfaces. The most appropriate data would be measurements of dislodgeable residues, but this type of data was not available for the insecticides. In most cases, measurements of total plant residues over time were available, so this data has been used to calculate degradation rates in those cases where surface measurements were unavailable. Degradation rates calculated in this way should be considered minimum degradation rates for dislodgeable residues, because the residues that were measured in deriving the data may have been largely or entirely unavailable for dermal exposure through vegetation contact.

Representative Wildlife Species

Wildlife exposures were calculated for a group of wildlife species representative of those typically found in areas supporting forest vegetation in the Pacific Northwest. These species represent a range of phylogenetic classes, body sizes, and diets. The methodology used to determine the exposures is the same as that used in the environmental impact statements prepared by the U.S. Department of Justice, Drug Enforcement Administration, on the eradication of cannabis with herbicides (DEA, 1985, 1986), and the environmental impact statement prepared by the U. S. Department of the Interior, Bureau of Land Management on the control of noxious weeds with herbicides (BLM, 1987). Table 3-22 lists the representative wildlife species and gives the various biological parameters used for each species in the exposure analysis. Table 3-23 lists of diet of each representative species.

Wildlife Exposure Estimates

Realistic and extreme acute exposure estimates were made for each representative species for each of the three major exposure routes: inhalation, dermal, and ingestion. Because the insecticides degrade relatively rapidly and sites are normally treated once per year, no analysis of chronic wildlife dosing was done. Because the insecticides show no tendency to bioaccumulate, as discussed in section 2, long-term persistence in food chains and subsequent toxic effects were not considered a problem and were not examined in the risk analysis.

Insecticide doses for the representative species were calculated using conservative, simplified assumptions concerning routine application operations that give realistic dose estimates and higher (extreme) dose estimates in which animals are directly sprayed. Exposures for realistic and extreme cases were based on the typical and maximum insecticide application rates.

For realistic doses, dermal exposures were based on the insecticide residue levels likely to be found on vegetation leaf surfaces because the animals are assumed to seek cover during a spraying operation. Extreme dose levels were estimated by assuming that animals do not seek cover and thus receive the full insecticide application rate on their entire body surface.

The dermal penetration rates used in the human exposure analysis were used to determine mammalian wildlife dermal penetration (that is, the amount of chemical that penetrates the animal's skin). In both realistic and extreme exposures, mammals are assumed to receive an oral dose from grooming their fur and birds are assumed to receive an oral dose from preening their feathers. This amount is subtracted from the amount they would receive as a dermal exposure through their skin.

Realistic ingestion doses were assumed to come from animals eating a specified percentage of their daily food intake in contaminated items based on their body size. That is, the percentage of contaminated food intake decreased as body size increases because larger animals are assumed to be more far ranging in obtaining food and would therefore be more likely to obtain some part of their diet away from the sprayed area. In the extreme case, the animals are assumed to feed entirely on contaminated food items.

Inhalation exposures are assumed to come from a hypothetical amount of insecticide droplets forming a "cloud" that moves slowly offsite.

The total systemic dose to each animal was calculated as the sum of the estimated doses received by way of dermal, ingestion, and inhalation routes. Tables 4-16 to 4-20 in the wildlife risk analysis in section 4 give the total realistic and extreme dose estimates for the representative species.

Exposure Calculations

Inhalation Exposures. Wildlife inhalation exposures were assumed to come from animals breathing in insecticide spray droplets of respirable size (30 microns in diameter or less) as a hypothetical "cloud" of those droplets moves slowly offsite. The cloud is assumed to be dispersed within the first 10 m above ground level on a 202.5 ha (500 acre) site 1,423 m on a side and to consist of respirable droplets that constitute 10 percent of the total applied insecticide by volume. Based on these assumptions, the airborne concentration is 0.002242 mg/L for each 1.12 kg/ha (1 lb/acre) applied. The cloud moves offsite at 0.9 m/sec (2 mph) and exposes animals on the downwind edge for 26.4 minutes in the realistic case. The wind is assumed to be 0.45 m/sec (1 mph) in the extreme case so that animals are exposed for 52.8 minutes. The nominal exposure was multiplied by the herbicide application rate and then by each animal's breathing rate. Their breathing rate in liters per minute is based on the following questions:

Birds: $$LMP = \frac{284 \times (BWT/1000)^{0.77}}{1,000}$$

Mammals: $$LPM = \frac{379 \times (BWT/1000)^{0.80}}{1,000}$$

Reptiles: LPM = o.00334

Amphibians: LPM = 0.007

Where:

LPM is the animal's breathing rate in liters per minute

BWT is the animal's body weight in grams

The equations for birds and mammals were taken from Lasiewski and Calder (1971). The reptile value is from a Gordon et al. (1986) study on the collard lizard. The breathing rate for amphibians was from Hutchinson et al. (1968). As anticipated, the animal modeling results showed inhalation exposures to be only a small fraction of each species total dose.

Dermal Exposures. Dermal exposures are assumed to come from two sources: (1) directly from insecticide spray at the deposition rate that should occur on vegetation leaf surfaces in the realistic case and at the insecticide application rate in the extreme case,and (2) indirectly by contact with contaminated vegetation.

Fur, feathers, and scales afford varying degrees of protection against dermal exposure; by preventing the chemical from reaching the animal's skin, they may instead allow the chemical to dry or to be rubbed off in their movements. For this reason, the dermal penetration rate for each insecticide fro mammals was adjusted for three other animal classes--birds, reptiles, and amphibians using reasonable assumptions for the differences between the classes. Dermal penetration factors were multiplied by the mammalian penetration rate as follows: (1) birds, 0.75; (2) reptiles, 0.15; and (3) amphibians, 5. The amphibian factor is high because the moist, glandular skin of the amphibian serves to a large extent as a respiratory organ and is much more permeable than the skin of the other animal classes [an average of 30 percent (5 to 93 percent) of body weight in water moves through skin in 24 hours according to Moore, 1964].

Wildlife may receive indirect dermal exposure from moving through contaminated vegetation by transferring pesticide from the vegetation to their body surface. The amount transferred would depend on (1) the density of the vegetation, (2) the animal's body size in relation to the height of the vegetation, and (3) the amount of movement of the animal.

To simplify the analysis, it was assumed that a certain percentage of the animal's total body surface received insecticide at the same level as the direct dermal exposure (either the level on leaf surfaces in the realistic case or at the application rate in the extreme case). That percentage was based on the animal's body size and a movement factor (MVF) to adjust for the taxonomic class. (Mammals, for example, are expected to move more than amphibians.) The animal's total body surface area was assumed to be a function of its weight according to the following formula (Kendeigh, 1970; Schmidt-Nielsen, 1972):

$$BSA = 10 \times (BWT)^{0.667}$$

where:

BSA is the animal's body surface area in cm^2

BTW is the animal's body weight in grams

The animal's vegetation contact percent (VCP) is based on its body weight in grams (BWT) according to the following formula:

$$VCP = 2.89\ (BWT)^{-0.3775}$$

The class adjustment factors (MVF's) for differing movement are as follows: (1) birds, 0.8; (2) mammals, 1; (3) reptiles, 0.3; and (4) amphibians, 0.4. The indirect dermal dose (IND) is then calculated using the direct dermal dose (DDD):

$$IND = DDD + VCP \times MVF)$$

Mammals and birds groom themselves regularly and may receive an ingestion dose if their fur or feathers are contaminated. The percent of their body surface groomed (PBG) was assumed to be a decreasing function of their body six according to the following formula:

$$PBG = 1.72\ (BWT)^{-0.29}$$

No grooming was assumed for reptiles and amphibians. The oral dose for mammals and birds from grooming was subtracted from the amount of insecticide that would contribute to the animal's dermal dose.

Ingestion Doses. Each representative species was assumed to feed on contaminated food items according to a specified diet and to drink a specified amount of water. These dietary amounts are listed in Table 3-23. Diets may vary from season to season and across the species range; the diet items and amounts were chosen to be a reasonable representation of what an individual animal might consume on a certain day. The diet items--grass, forage vegetation, seeds, insects, and berries--are assumed to have the following contamination levels in ppm from ground application, based on field studied by Hoerger and Kenaga (1972) for a 1-lb/acre application rate.

	Realistic	Extreme
	ppm	
Grass	1.665	92
Forage	0.439	33
Seeds	0.040	3.2
Insects	0.0627	4.8
Berries	0.0199	1.6

Water is assumed to be drunk in the realistic case from a stream offsite that reaches a concentration of 0.001267 ppm per pound of insecticide applied per acre for aerially applied insecticides and 0.0003 ppm for ground-applied insecticides. In the extreme case, water reaches a concentration of 0.0068 ppm for aerially applied insecticides and 0.00063 ppm for ground-applied insecticides. Predators that feed on mice or toads are assumed to receive the total body burden that each of these prey species has received through the three exposure routes described above as a result of the insecticide spraying operation. Predators that feed on fish (piscivores) are assumed to receive residue levels based on the concentration in the water. In the realistic exposures, each species is assumed to consume a percentage of its daily intake in contaminated food items, depending on its body size. The percentages of food contaminated (PFC) are based on the following formula:

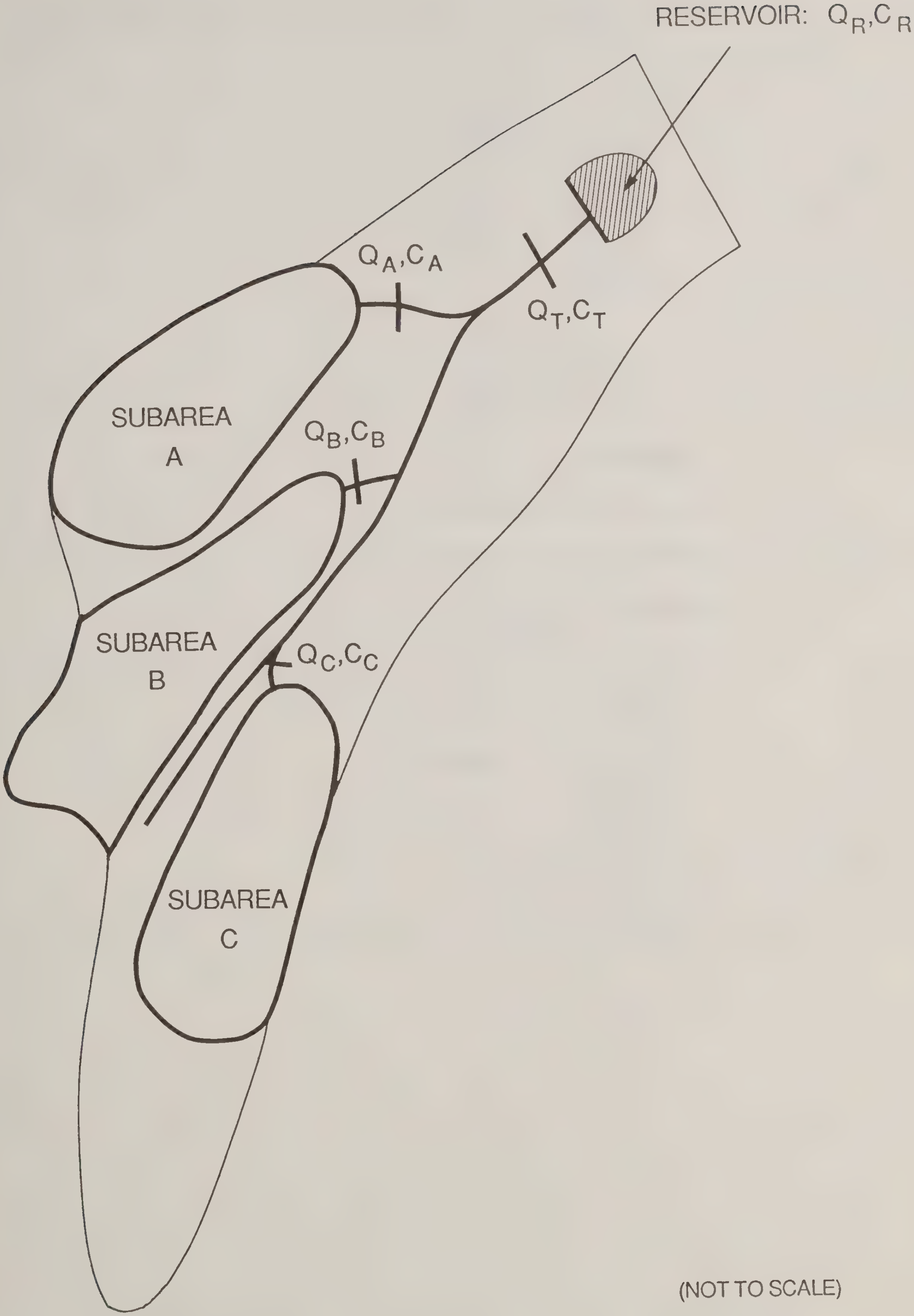
$$PFC = 100 \times (1/(BWT)^{.2}$$

In the extreme case, each species' entire daily food intake is assumed to consist of insecticide-contaminated items.

AQUATIC SPECIES EXPOSURE ANALYSIS

Representative species typical of aquatic habitats in the U. S. Forest Service Region 6 were used to estimate risk to aquatic organisms. These species are listed in Table 3-24. These organisms were assumed to be exposed to insecticide and petroleum distillate residues by immersion in bodies of water.

Typical and maximum estimated environmental concentration (EEC's) of each insecticide were calculated for a body of water 0.61 meters (1 feet) deep as described in the human exposure analysis. The EEC's are given in Table 3-25. EEC's also were calculated for a spill of a 200-gallon load of mixture into a 1-acre pond and for direct spraying of a pond at the full application rate. Risk to aquatic species from these EED's is presented in Section 4.



RESERVOIR: Q_R, C_R
Q_A, C_A
Q_T, C_T
SUBAREA A
Q_B, C_B
SUBAREA B
Q_C, C_C
SUBAREA C

(NOT TO SCALE)

Table 3-1--Potential insecticides for spruce budworm control.

Product name	EPA number	Registrant	Normal use rates[a]
	Carbaryl		
Sevin Brand 4-Oil	264-323	Rhone-Pulenc,	0.5 to 1 lb a.i./acre
Sevin Brand 80 S	264-316	"	
Sevin Brand 50 W	264-314	"	
Acephate			
Orthene Specialty Concentrate	329-2486-AA	Chevron Chemical Co.	0.5 lb a.i./acre
Orthene 75 S	239-2418-AA	"	
	Malathion		
Cythion-Malathion ULV Concentrate	241-208-AA	American Cyanamid Co.	0.9 to 1 lb a.i./acre
	Bacillus Thuringiensis		
Dipel 6 L	275-48	Abbott Laboratories	
Dipel 6 AF	275-59	"	
Dipel 8 L	275-51	"	
Javelin	55947-80	Sandoz Corp.	12 B.I.U./acre
Thuricide 32 B	55947-62	"	
Thuricide 48 LV	55947-74	"	
Bactospeine WP	43382-2	PBI/Gordon Corp.	
Bactospeine FC	43382-5	"	

[a]Actual application, including carrier, will be approximately 0.5 gallon per acre.

Table 3-2--Food plants found on Indian reservations and National Forests in

big leaf huckleberry	Vaccinium membranaceum
camas	Camassia quamash, C. leichtlinii
sawtik	Perideridia gairdneri
black lichen	Bryoria fremontia
chokecherry	Prunus virginiana
bitterroot	Lewisia deviviva
coush	Lomatium cous
biscuitroot	Lomatium cnabyi
Piper's lomatium	Lomatium piperi
Indian celery	Barestem lomatium
Gray's lomatium	Lomatium grayi
dwarf huckleberry	Vaccinium caespitosum
blue-leaf huckleberry	Vaccinium deliciosum
oval-leaf huckleberry	Vaccinium ovalifolium
cranberry	Vaccinium oxycoccus
dwarf Oregon grape	Berberis nervosa
hazelnut	Corylus cornuta
pine nuts	Pinus albicaulus, P. Lambertiana
strawberry	Fragaria virginiana, F. vesca
serviceberry	Admelanchier alnifolia
hawthorn	Crataegus douglasii
elderberry	Sambucus cerulea
acorns	Quercus garryana
thimbleberry	Rubus parviflorus
blackberries	Rubus spp.
mint	Mentha arvensis
mountain monardella	Monardella odoratissima
skunk cabbage	Lysichitum americanum

Source: Helliwell, 1988.

Table 3-3--Worker exposure times.

	Number	(Exposure) Days (actual spray days)	Hours/day (actual)
Forest Service			
Director	1	12-15	2
Operations leader	1	12-15	2
Application leader	3	12-15	2
Aerial observers[a]	10	12-15	2
Load checkers[a]	5	12-15	2
Ground observers[a]	15	12-15	3
Spray assessment crew[a]	25	12-15	3
Biological (entomology) evaluation crew[b]	15	12-15	3
Safety officer	1	12-15	2
Law enforcement	4	12-15	2
TOTAL	80		
Application pilot	10	12-15	2
Observation pilot[a]	10	12-15	2
Batch truck operator[a]	5	12-15	2
Fuel truck operator	5	12-15	2
Mechanic/laborer[a]	2	12-15	2
TOTAL	32		

[a]Potential direct exposure during application.
[b]Potential delayed exposure (2+ hours after spray).

Note: The average treatment block will be approximately 2,000 to 10,000 acres.

Table 3-4--Routes of exposure evaluated in this risk assessment for workers and members of the public

Workers
Pilot - Inhalation and dermal
Mixer/loader - Inhalation and dermal
Observer - Inhalation and dermal
Card checker - Dermal
Entomology efficacy team member - Dermal
Public
Nearby residents or recreationalists:
Dermal from vegetation contact
Dermal and inhalation from drift
Dietary from consumption of water, fish, deer meat, garden items (peas or beans), wild berries
Fisherman - cumulative exposure - dermal (vegetation contact) and dietary (water and fish)
Hunter - cumulative exposure - dermal (vegetation contact) and dietary (water, wild berries, and deer meat)

Table 3-5 Riverbasin Characteristics

<u>Common data used to model subareas A, B and C</u>

Area = 7.81 square miles

Root Zone Depth = 66 inches

SCS Curve Number = 65

Soil Erodibility Factor = 0.10

Erosion Control Practice Factor = 1.0

Slope-length and Steepness Factor = 10

Saturated Hydraulic Conductivity with Depth = 3.0-0.2 in/hr

<u>Characteristics of 3 Most Common Soil Types</u>

Bulk density [tons/cubic meter] = 1.22, 1.16, 0.92

Porosity = 0.54-0.49, 0.41-0.51, 0.38-0.41

Soil Water Content at 0.3 bars = 0.25, 0.24, 0.19

Soil Water Content at 15 bars = 0.08, 0.06, 0.06

(Source: USDA, 1979; Knisel, 1980; NDSA, 1980)

Table 3-6 Insecticide Characteristics

Pesticide	Kd -	Foliar Half-Life (days)	Soil Decay Constant (day^{-1})	Application Rate (lb/acre)
Acephate	0.1	2.8	0.17	0.50
Malathion	34.1	2.4	1.825	1.00
Carbaryl	2.2	6.8	0.1064	0.51

(Source: Rose, 1988; Knisel, 1980)

Table 3-7 Estimated Insecticide concentrations in Runoff

Pesticide	Subarea	Runoff (inches)	Pesticide in runoff (lb/acre)	Runoff Concentration (ppb)
Acephate	A	0.108	0.00061	25
	B	0.109	0.00056	23
	C	0.108	0.00061	25
	Combined			24
	Runoff Reservoir			3.6
Malathion	A	0.108	0.00040	16
	B	0.109	0.00054	22
	C	0.108	0.00085	35
	Combined Runoff			24
	Reservoir			3.6
Carbaryl	A	0.108	0.00351	140
	B	0.109	0.0033	130
	C	0.108	0.0030	120
	Combined Runoff			130
	Reservoir			20

Table 3-8 Estimated insecticide concentrations in soil water.

Pesticide	Subarea	Soil Water (inches)	Pesticide Leached (lb/acre)	Leachate Concentration (ppb)
Acephate	A	3.63	0.180	35
	B	4.25	0.232	39
	C	3.78	0.298	56
	Combined Runoff			
	Reservoir			
Malathion	A	3.63	0.0099	1.9
	B	4.25	0.0149	2.5
	C	3.78	0.0250	4.7
	Combined Runoff			
	Reservoir			
Carabaryl	A	3.63	0.249	49
	B	4.25	0.288	48
	C	3.78	0.335	63
	Combined Runoff			
	Reservoir			

Table 3-9 Insecticide Application Rates and Mass Impacts

compound	application rate		mass input		
	typical	worst	typical	worst	average
acephate	0.5	0.5	0.994	3.09	1.55
carbaryl	0.26	0.51	0.52	3.15	1.58
malathion	0.9	1.0	1.79	6.17	3.09
diesel	0.85	1.7	1.69	10.5	5.25
kerosene	0.24	0.49	0.474	3.02	1.51

Table 3-10--Average mass input of insecticide (mg/sq ft) and estimated concentrations (ug/l or ppb) in Crow Creek Reservoir, The Dalles Watershed Management Unit, OR.

Compound	average mass input	concentration
acephate	1.55	1.98
carbaryl	1.58	2.02
malathion	3.09	3.95
diesel	5.25	6.72
kerosene	1.51	1.93

Table 3-11--Estimated concentration (ug/kg plant or ppb) of insecticides in plants irrigated by contaminated water.

Compound	Concentration
acephate	38.76
carbaryl	12.77
malathion	176.4
diesel	209.6
kerosene	60.2

Table 3-12 Exposures Considered in the Risk Assessment

Public Exposures:

- Inhalation exposures from insecticide drift.
- Dermal exposures from drift and from contact with sprayed vegetation.
- Ingestion exposures from drinking water and from eating fish, game meat, peas or beans, or berries.

Workers Exposures:

- Exposures to pilots, mixer/loaders, observers, card checkers, E.E. team members, and backpack applicators.

Accident Exposures:

- Spills of insecticide concentrate onto a worker
- Broken hose spilling mixture onto a worker
- Direct spraying of an adult.
- Direct spraying of a child.
- 200-gallon spill into a pond.

Table 3-13 ACEPHATE Exposures

	Exposure (mg/kg/day) Typical	Worst Case
PUBLIC		
Dermal		
Veg Contact	0.00021	0.00021
Dermal & Inhalation		
Drift	0.00293	0.00900
Dietary		
Water	0.00050	0.00155
Fish	0.00125	0.00388
Meat	0.00023	0.00070
Peas or Beans	0.00391	0.00996
Berries	0.00196	0.00520
Cumulative		
Fisherman	0.00197	0.00565
Hunter	0.00290	0.00767
WORKERS		
Pilot	0.00084	0.00162
Mixer/Loader	0.00187	0.00489
Observer	0.00293	0.00900
Card Checker	0.00357	0.00725
E.E. Team	0.00000	0.00000
Backpack	0.00857	0.04122
ACCIDENTS		
Spill Onto Worker		85.7143
Broken Hose		42.8571
Direct Spray - Adult		0.0149
Direct Spray - Child		0.0223
Peas or Beans		0.0169
Spill Into Water		
200 Gal Into Pond		1,0522

Table 3-14 CARBARYL Exposures

PUBLIC		
Dermal		
Veg Contact	0.00011	0.00022
Dermal & Inhalation		
Drift	0.00152	0.00918
Dietary		
Water	0.00026	0.00158
Fish	0.00007	0.00040
Meat	0.00012	0.00072
Peas or Beans	0.00203	0.01016
Berries	0.00102	0.00530
Cumulative		
Fisherman	0.00044	0.00220
Hunter	0.00151	0.00782
WORKERS		
Pilot	0.00044	0.00165
Mixer/Loader	0.00097	0.00499
Observer	0.00152	0.00918
Card Checker	0.00197	0.00773
E.E. Team	0.00047	0.00363
Backpack	0.00446	0.04204
ACCIDENTS		
Spill Onto Worker		171.4286
Broken Hose		43.7143
Direct Spray - Adult		0.0152
Direct Spray - Child		0.0228
Peas or Beans		0.0173
Spill Into Water		
200 Gal Into Pond		1.0732

Table 3-15 MALATHION Exposures

	Exposure (mg/kg/day) Typical	Worst Case
PUBLIC		
Dermal		
Veg Contact	0.00027	0.00030
Dermal & Inhalation		
Drift	0.00374	0.01270
Dietary		
Water	0.00090	0.00311
Fish	0.00023	0.00078
Meat	0.00039	0.00130
Peas or Beans	0.00704	0.01991
Berries	0.00352	0.01040
Cumulative		
Fisherman	0.00140	0.00418
Hunter	0.00508	0.01511
WORKERS		
Pilot	0.00108	0.00230
Mixer/Loader	0.00238	0.00690
Observer	0.00374	0.01270
Card Checker	0.00478	0.01065
E. E. Team	0.00257	0.00853
Backpack	0.01080	0.05770
ACCIDENTS		
Spill Onto Worker		279.9000
Broken Hose		60.0000
Direct Spray - Adult		0.0209
Direct Spray - Child		0.0313
Peas or Beans		0.0339
Spill Into Water		
200 Gal Into Pond		2.1043

Table 3-16 DIESEL Exposures

	Exposure (mg/kg/day) Typical	Worst Case
PUBLIC		
Dermal		
Veg Contact	0.00091	0.00182
Dermal & Inhalation		
Drift	0.01224	0.07564
Dietary		
Water	0.00085	0.00528
Fish	0.00277	0.01716
Meat	0.00047	0.00326
Peas or Beans	0.00665	0.03385
Berries	0.00333	0.01768
Cumulative		
Fisherman	0.00453	0.02426
Hunter	0.00555	0.02804
WORKERS		
Pilot	0.00349	0.01351
Mixer/Loader	0.00780	0.04117
Observer	0.01224	0.07564
Card Checker	0.01632	0.06528
E. E. Team	0.09792	0.26112
Backpack	0.03644	0.35034
ACCIDENTS		
Spill Onto Worker		728.5715
Broken Hose		364.2857
Direct Spray - Adult		0.1266
Direct Spray - Child		0.1899
Peas or Beans		0.0576
Spill Into Water		
200 Gal Into Pond		3.5773

Table 3-17 KEROSENE Exposures

	Exposure (mg/kg/day) Typical	Worst Case
PUBLIC		
Dermal		
Veg Contact	0.00026	0.00052
Dermal & Inhalation		
Drift	0.00346	0.02180
Dietary		
Water	0.00024	0.00152
Fish	0.00078	0.00495
Meat	0.00013	0.00094
Peas or Beans	0.00188	0.00976
Berries	0.00094	0.00510
Cumulative		
Fisherman	0.00128	0.00699
Hunter	0.00157	0.00808
WORKERS		
Pilot	0.00098	0.00389
Mixer/Loader	0.00220	0.01187
Observer	0.00346	0.02180
Card Checker	0.00461	0.01882
E. E. Team	0.02765	0.07526
Backpack	0.01029	0.10098
ACCIDENTS		
Spill Onto Worker		728.5715
Broken Hose		105.0000
Direct Spray - Adult		0.0365
Direct Spray - Child		0.0547
Peas or Beans		0.0166
Spill Into Water		
200 Gal Into Pond		1.0311

Table 3-18 PETROLEUM DISTILLATE Exposures

	Exposure (mg/kg/day) Typical	Worst Case
PUBLIC		
Dermal		
Veg Contact	0.00116	0.00234
Dermal & Inhalation		
Drift	0.01570	0.09745
Dietary		
Water	0.00109	0.00680
Fish	0.00355	0.02211
Meat	0.00060	0.00420
Peas or Beans	0.00853	0.04361
Berries	0.00426	0.02278
Cumulative		
Fisherman	0.00580	0.03125
Hunter	0.00712	0.03612
WORKERS		
Pilot	0.00447	0.01740
Mixer/Loader	0.01000	0.05303
Observer	0.01570	0.09745
Card Checker	0.02093	0.08410
E. E. Team	0.12557	0.33638
Backpack	0.04672	0.45132
ACCIDENTS		
Spill Onto Worker		728.5715
Broken Hose		469.2857
Direct Spray - Adult		0.1631
Direct Spray - Child		0.2447
Peas or Beans		0.0741
Spill Into Water		
200 Gal Into Pond		4.6084

Table 3-19 B. thuringiensis Exposures

	Exposure (mg/kg/day) Typical	Worst Case
PUBLIC		
Dermal		
Veg Contact		------
Dermal & Inhalation		
Drift	0.00028	0.00075
Dietary		
Water	0.00165	0.00683
Fish		-----
Meat		-----
Peas or Beans	0.01291	0.04381
Berries	0.00645	0.02288
Cumulative		
Fisherman	0.00165	0.00683
Hunter	0.00811	0.02971
WORKERS		
Pilot	0.00012	0.00023
Mixer/Loader	0.00017	0.00037
Observer	0.00028	0.00075
Card Checker		-----
E. E. Team		-----
Backpack		-----
ACCIDENTS		
Spill Onto Worker		-----
Broken Hose		-----
Direct Spray - Adult		-----
Direct Spray - Child		-----
Peas or Beans		0.0745
Spill Into Water		
200 Gal Into Pond		4.6295

Table 3-20 Human exposure to pesticides.

Pesticide	Subarea	Concentration (ppb)	Human Dose (mg/kg/day)
Acephate	A	25	0.000711
	B	23	0.000649
	C	25	0.000711
	Reservoir	3.6	0.000103
Malathion	A	16	0.000466
	B	22	0.000626
	C	35	0.000991
	Reservoir	3.6	0.000104
Carabaryl	A	140	0.0041
	B	130	0.00382
	C	120	0.0035
	Reservoir	20	0.00057

Table 3-21--Estimated daily dose (mg/kg/day) of insecticides to humans from consumption of crops grown with contaminated irrigation water and margin of safety (MOS).

Compound	Dose
acephate	0.000277
carbaryl	0.000091
malathion	0.00126
diesel	0.00150
kerosene	0.00043

Table 3-22--Representative wildlife and domestic species and associated biological parameters.

Representative niche	Representative species	Body weight (grams)	Daily food intake (grams)	Percent of food contaminated in realistic case	Body surface area (cm2)	Body surface contacting vegetation (percent)	Percent of body groomed	Inhalat volum (L/mi
Insectivorous birds	Flicker	75	15	42	178	57	49	0.03
Granivorous birds	Dove	100	11	40	216	51	45	0.04
Omnivorous birds	Jay	70	14	43	170	58	50	0.03
Piscivorous birds	Kingfisher	250	50	33	398	36	35	0.09
Carnivorous birds	Owl	100	20	40	216	51	45	0.04
Small Omnivorous mammals	Mouse	20	6	55	74	93	72	0.01
Medium Herbivorous mammals	Rabbit	1,350	110	24	1,224	19	21	0.48
Large Herbivorous mammals	Deer	68,000	2,500	11	16,722	4	7	11.1
Carnivorous mammals	Fox	5,670	475	18	3,189	11	14	1.52
Insectivorous amphibians	Toad	22	5	54	79	90	0	0.00
Carnivorous reptiles	Snake	40	22	48	117	72	0	0.00
Domestic animals	Cattle	453,590	12,000	7	59,292	2	4	50.6
	Chicken	2,000	300	22	1,591	16	19	0.48
	Dog	13,000	NA	NA	5,715	8	11	3.06

NA = Not applicable or not available.

Table 3-23--Representative wildlife species diet items.[a]

Representative species	Water	Grass	Forage	Seeds	Insects	Berries	Mouse	Toad	Fish
Birds									
Flicker	0.02	0	0	0	15	0	0	0	0
Mourning dove	0.05	0	0	11	0	0	0	0	0
Jay	0.05	0	0	5	5	4	0	0	0
Kingfisher	0.08	0	0	0	0	0	0	0	50
Screech owl	0.05	0	0	0	0	0	20	0	0
Mammals									
Mouse	0.05	0	1	2	3	0	0	0	0
Rabbit	0.05	110	0	0	0	0	0	0	0
Deer	1.5	500	2,000	0	0	0	0	0	0
Fox	0.8	0	0	0	0	175	300	0	0
Amphibian									
Toad	0.05	0	0	0	5	0	0	0	0
Reptile									
Snake	0.01	0	0	0	0	0	0	22	0
Domestic animals									
Cow	58	12,000	0	0	0	0	0	0	0
Chicken	0.10	0	0	300	0	0	0	0	0
Dog	0.50	0	0	0	0	0	0	0	0

[a] Consumption in liters for water and in grams for all other items.

Section 4

RISK ANALYSIS

This section describes the potential risks to human health and the environment from the proposed spruce budworm suppression program. Human health risks to workers and members of the public are evaluated as well as effects on wildlife and aquatic species by comparing estimated insecticide exposures to toxicity levels found in laboratory studies. The first subsection describes the methods used to evaluate human health risks. The second subsection evaluates the risks of threshold effects, which include acute toxic effects, chronic systemic effects, and reproductive (fetotoxic and maternal toxic) and developmental (teratogenic) effects. The third subsection evaluates the risks of the insecticides causing cancer or mutagenic effects in the population at risk. The fourth subsection describes related human health risks, including synergistic and cumulative effects, effects on sensitive individuals, and the effects of inert ingredients. The fifth subsection describes risks to wildlife and aquatic species. All judgments about risk are discussed in the light of the probabilities of the estimated exposures actually occurring.

METHODS OF EVALUATING HUMAN HEALTH RISKS

Health risks to humans exposed to the insecticides were quantified by comparing the doses estimated in the range of exposure scenarios presented in section 3 with the results of toxicity tests on laboratory animals listed in table 4-1 and described in section 2.

For the analysis of the risk of threshold effects, margins of safety (MOS's) are computed in this analysis by dividing a NOEL from an animal study by an estimated human dose. For example, an MOS of 100 means the laboratory-determined level is 100 times higher than the estimated dose. The MOS is used to account for the uncertainty in extrapolating from a dose that produces no observed effects in laboratory animals to a dose that should produce no adverse effects in exposed humans. An uncertainty factor of 10 has normally been used in the estimation of safe levels in humans from experimental studies when valid human studies are available and no indication of carcinogenicity exists. An uncertainty factor of 100 is used when few or no human studies are available but valid long-term animal studies are available; when very limited toxicological data are available, a safety factor of 1,000 or greater could be used to estimate acceptable human exposure. Although the computed MOS's correspond with the uncertainty factors that EPA uses to determine Reference Doses (RfD's), they are applicable only to this risk assessment. Also, a margin of safety does not always mean that the dose is safe. An MOS of three, for example, could represent a risk of toxic effects for repeated exposures.

For doses that are not likely to occur more than once, such as those received by workers spilling spray mix on their upper body, a dose estimate that exceeds the laboratory test animal NOEL does not necessarily lead to the conclusion

that there will be toxic effects. All the NOEL's in this risk analysis are based on (or take into account) long-term exposure. Estimated doses that exceed the NOEL are compared to the insecticide's acute oral LD_{50} so that a judgment can be made on the risk of fatalities.

The larger the margin of safety (the smaller the estimated human dose compared to the animal NOEL), the lower the risk to human health. As the estimated dose to humans approaches the animal NOEL (as the MOS approaches one), the risk to humans increases. When an estimated dose exceeds a NOEL (giving an MOS of less than one), the ratio is reversed (the dose is divided by the NOEL) to indicate how high the estimated dose is above the laboratory toxicity level; and a minus sign is attached to indicate that the dose exceeded the NOEL. A ratio of -3, for example, means that the estimated dose is three times the laboratory-determined level.

In general, when repeated doses to humans approach the animal NOEL (the MOS is less than 10), there is some possibility of harmful effects. In general, when the MOS is less than 100, sensitive individuals may be at risk. Conversely, when the human dose is small compared with the animal NOEL (giving an MOS greater than 100), the risk to humans can be judged as very low. Comparing one-time or once-per-year doses (such as those experienced by the public) to NOEL's derived from lifetime studies tends to greatly overestimate the risk from those rare events.

Systemic effects are evaluated based on the lowest systemic NOEL found in a 2-year feeding study of dogs, rats, or mice. Reproductive effects are evaluated based on the lowest maternal, fetotoxic, or teratogenic NOEL found in a reproductive study or in a teratology study.

Risk to human health from the use of *Bacillus thuringiensis* are evaluated based on the available evidence of toxicity of this biological pesticide in studies of exposed humans and laboratory animals. An MOS value is calculated for inhalation and oral *B.t.* exposures. However, these MOS's may not be appropriate in the case of *B.t.* since much of the rationale involving MOS is derived from known genetic differences in chemical metabolism, DNA repair, detoxification of molecules, and dexcretion of metabolites, none of which applies to *B.t.* *B.t.* effects on reproduction are not known so no MOS for those effects could be calculated.

A worst-case analysis of cancer risk is conducted for the insecticides and for diesel oil and kerosene. No risk linking *B.t.* with cancer is available so cancer risk was not done for *B.t.* The risk of cancer is calculated for an individual by multiplying estimates of lifetime dose over a 70-year period by cancer potency estimates derived in the hazard analysis section. A worst-case analysis also is conducted for those insecticides that have positive mutagenicity tests or those for which no data are available. The risk of these insecticides causing mutations is qualitative rather than quantitative, with a statement of the probable risk based on the available evidence of mutagenicity and carcinogenicity.

RISK OF GENERAL SYSTEMIC AND REPRODUCTIVE EFFECTS

Margins of safety were computed for workers and the public for routine operations (typical and worst-case exposures) and accidents for the three

insecticides, for diesel oil and kerosene in carbaryl applications and for B.t. Table 4-2 summarizes the margin-of-safety results for typical exposures for the five chemicals. Table 4-3 summarizes the MOS's for routine-worst case exposures. Tables 4-4 to 4-9 list the margins of safety for each chemical and for B.t. The margins of safety were computed by comparing the laboratory-determined NOEL's in table 4-1 with the doses shown in section 3.

Risk to the Public in Routine Operations

Risk to the Public From Routine-Typical Exposures

Table 4-2 shows that margins of safety for the public in routine typical spraying are greater than 100 for systemic effects for carbaryl, diesel oil, kerosene, and B.t. Margins of safety for reproductive effects for the three chemical insecticides also are all greater than 100. These large margins of safety mean that members of the public could be repeatedly exposed to these levels and suffer no adverse effects.

MOS's for systemic effects for acephate and malathion are greater than 100 for all individual exposure routes except for dermal and inhalation exposure from drift and exposure from eating peas or beans. The MOS for malathion from eating berries is also less than 100. Cumulative exposures to fishermen lead to MOS's greater than 100 for all 5 chemicals, but hunter cumulative exposures for acephate and malathion give MOS's of less than 100. MOS's for acephate and malathion for reproductive effects are all greater than 100.

These results indicate that no reproductive effects are likely to result from the use of insecticides in spruce budworm suppression operations but that acephate and malathion could cause systemic effects, most likely in increased acetylcholinesterase inhibition levels, in exposed members of the public.

Risk to the Public From Routine-Worst Case Exposures

The routine-worst case scenarios described in section 3 were intended to indicate the upper bound for public exposure to insecticide applications in the Pacific Northwest. The low probability of occurrence of each event that is assumed to occur that led to the estimated exposures must be emphasized. It is extremely unlikely that anyone would receive a dose as high as those estimated here.

Margins of Safety From Routine-Worst Case Exposures. Table 4-3 indicates that MOS's for reproductive effects are greater than 100 for all chemicals for the routine-worst case exposures. Margins of safety for systemic effects projected under this routine-worst case scenario are greater than 100 for carbaryl and kerosene. MOS's for diesel oil are greater than 100 except for dermal and inhalation exposure to drift.

Margins of safety for systemic effects for acephate and malathion are less than 100 for a number of individual exposure routes and for cumulative exposures to fishermen and hunters.

These results indicate that there is a greater risk of systemic effects, most likely increased levels of acetylcholinesterase inhibition, for acephate and

malathion than under the typical spraying conditions and that there is some slight risk of effects from diesel oil drift exposure.

Table 4-3b shows margins of safety for persons drinking contaminated water from runoff in the Dalles Watershed analysis. None of the MOS's are lower than 100 for any of the feeder streams. MOS's are greater than 1000 for the reservoir itself so there is little risk from runoff when large areas of a watershed are sprayed even when rain occurs immediately after spraying.

Margins of safety for persons eating crops irrigated with contaminated water are given in Table 4-3c. MOS's are all greater than 100 indicating very low risk from this potential route of exposure.

Risk to the Public in Accidents

Table 4-10 summarizes the risk to the public from direct exposure to aerial spray, from eating food directly hit at the highest application rate and from drinking water that has received a dump of 200 gallons of spray mix.

The extent of effects would depend upon their duration of exposure and any precautionary measures that were taken. For example, if people gathered a bushel of berries from a spray area and did not wash them but froze them and then ate them every day for a month, they might feel quite ill. However, if people bathed after being in the forest or washed food items before eating them, the doses would drop (and thus substantially increase the margins of safety).

Again, it must be noted that these are one-time, rather than repeat or chronic, exposures and that the comparison of these doses with the acute LD_{50}'s shows that no one is at risk of fatal effects.

Risk to Workers From Routine Operations

Tables 4-11 and 4-12 summarize the margins of safety for workers for routine-typical and routine-worst case exposures based on the systemic and reproductive NOEL's for the five chemicals.

Effects of the Use of Protective Clothing

It must be emphasized that the routine worker exposures and resultant margins of safety are what could be expected in most spruce budworm suppression programs in the Pacific Northwest for workers not wearing protective clothing or equipment. All of the studies from which the routine-realistic exposures were calculated are based on workers wearing no protective clothing. The use of protective clothing can substantially reduce worker doses, as shown in field studies of worker exposure, and thereby increase their margins of safety.

Protective clothing can reduce worker exposures by 27 to 99 percent, as shown in a number of relevant field studies. The calculated doses presented below were based on the assumption that workers work with bare hands and wear ordinary work clothing, such as cotton pants and short-sleeve shirts. It is common practice, however, for insecticide applicators to wear clothing that affords more protection. Typical clothing often includes long-sleeve shirts or coveralls, gloves, and hats.

Research has shown that such protective clothing can substantially reduce worker exposure. During insecticide applications to orchards, mixers reduced their exposure by 35 percent and sprayers reduced their exposure by 49 percent by wearing coveralls (Davies et al., 1982).

Risk to Workers From Routine-Typical Exposures

In the routine-typical exposures, all categories of workers applying carbaryl and kerosene have MOS's greater than 100. This indicates that even workers chronically exposed to these chemicals should suffer no ill effects. For acephate and malathion as shown in table 4-10, observers, card checkers and backpack sprayers had MOS's less than 100. Also for Malathion, mixer/loaders and E.E. team members had MOS's less than 100, as did the E.E. team members for diesel oil. This means that unprotected workers who routinely receive doses this high may experience some toxic effects from applying these insecticides.

Risk to Workers From Routine-Worst Case Exposures

As shown in table 4-11, acephate, carbaryl, malathion, and diesel oil all have MOS's less than 100 for routine-worst case exposure.

The probability of workers receiving repeated daily doses as high as predicted here is extremely low. Therefore, even if a worker felt ill for a day or so from an unusually high dose, permanent damage would be unlikely. Most of the time, workers will be receiving doses less than those predicted in the routine-worst case scenario. Sensitive individuals would be at greater risk.

Risk to Workers From Accidents

Dermal doses estimated in this analysis tend to exaggerate the amount that would actually be received because the dermal penetration rates used in the calculations assume no time factor is involved, that is, the chemicals penetrate the skin immediately. In reality, the penetration rates involve a significant time factor because they were derived from studies in laboratory animals over a period of one to several days. This means unprotected workers that routinely receive doses this high may experience some toxic effects from applying these insecticides. Thus, workers would have to ignore their own safety and not wash the chemical off to receive doses as high as predicted in these accidents.

Margins of safety for worker accidents are presented in table 4-13. Workers who spill 500 milliliters of insecticide concentrate or spray mix on their skin may experience acute toxic effects, in particular, high levels of acetylcholinesterase inhibition, if they do not wash the chemical off. In the case of a spill of 500 milliliters of concentrate, the doses approach the LD_{50}. The acephate dose is 10 percent of the LD_{50}; the carbaryl dose, 63 percent of the LD_{50}; the malathion dose, 75 percent of the LD_{50}; the diesel oil dose, 10 percent and the kerosene dose, 3 percent of the LD_{50}. For carbaryl and malathion in particular, this represents a clear risk of severe toxic effects if the chemical is not washed off.

Workers are not likely to be affected by carbaryl or kerosene if they are directly sprayed, but they may be affected by diesel oil (MOS = 58). MOS's for

acephate and malathion are relatively low for the worker accidentally sprayed, although they do not exceed the NOEL; so risks of severe effects are not as high as in the spills of concentrate or mix on their skin.

Risk to Humans from Bacillus thuringiensis

Risk of Direct Effects from *B.t.*

Margins of safety for *B.t.* exposures are given in table 4-9. Risks to humans from the Forest Service use of the current formulations of *Bacillus thuringiensis* appear to be negligible. The Dipel and Thuricide formations of *B.t.* are generally nontoxic to humans because they do not produce the two metabolic products alpha-exotoxin and beta-exotoxin that are known to be toxic to vertebrates.

There have been no reports of chronic health effects in workers exposed in the production of *B.t.*, although an incident involving a Dipel suspension that splashed into a farmer's eye suggested that *B.t.* may result in eye infection. Laboratory studies in which *B.t.* was applied directly to the eye of a rabbit showed no such infections. (Sassaman, 1987)

Skin irritation has been shown to be produced in rabbits treated with the Dipel 4L formulation of *B.t.*; however, no acute, subchronic, or chronic systemic toxicity has been shown in animal studies.

Risk of Effects from *B.t.* Contaminants (Bioburden)

John Ogle of Agriculture Canada reports a study in which three *B.t.* formulations were tested for contamination with other microorganisms. Dipel contained fecal streptococci at a level of one to ten million per billion international units of *B.t.* The manufacturer, Abbott Laboratories, was alerted and implemented measures that reduced the contaminant to a level of less than one thousand per billion international units. The Canadians plan to reduce this to less than 100.

The U.S. Forest Service has submitted samples of *B.t.* to the Food and Drug Administration for contaminant testing. Results are not available at this time.

Studies in humans who were administered *B.t.* by various routes (oral, ingestion, inhalation) have indicated no adverse effects at the doses tested (Sassaman, 1987). No definitive proof has been found that current *B.t.* formulations used by the Forest Service would contribute to the overall bioburden of human disease-causing microorganisms, such as virus or streptococcus. The Forest Service has described their current evaluation of the situation as follows USDA, 1988):

> In over 18 years of *B.t.* use, there have been no scientifically-documented cases or evidence of *B.t.*-caused illness directly attributable to forestry-use situations. This long history of use and a special study on the health effects of *B.t.* spray programs conducted by the Oregon Department of Human Resource's Health Division between 1985-87 have not resulted in [the identification of] any cause and effect relationships

between *B.t.* use and human illness. Thus, they appear to corroborate the apparent safety of this biological pesticide.

Low levels of extraneous microorganisms do exist in *B.t.*; however, these low levels do not affect the overall safety of *B.t.* The same environmental bacteria are also present at similar levels in water, food, milk, and other dairy products. The chances of exposure to low levels of extraneous microorganisms may be greater from eating or drinking ordinary food products than from *B.t.* use in forestry.

Another concern recently expressed was the possibility of enterotoxins being present in *B.t.* products. Manufacturers of *B.t.* products advise us that due to steps taken in the manufacturing process, it is unlikely that enterotoxins would be present in distributed products.

A final concern has been *B.t.* contamination of food or feed. Given current information, and under forestry use conditions, the probability of *B.t.* contaminating food or food products is highly unlikely. During all the years of *B.t.* use in agriculture and forestry, no evidence has been seen that *B.t.* grows on food, produces enterotoxins, significantly increases the bioburden, or causes unacceptable contamination.

Manufacturers of *B.t.* products are required by law to test each lot of *B t.* technical material produced. Each lot is tested for pathogenicity and vertebrate toxicity. Therefore, additional testing by the Forest Service is believed unnecessary.

Thus, it appears that humans exposed to *B.t.* in spruce budworm suppression operations may be at some low level of risk from eye or skin irritation or infection but are not at risk of any systemic effects from *B.t.*

CANCER RISK

A worst-case analysis for cancer was conducted for the three insecticides and for diesel oil and kerosene.

The cancer risks presented in table 4-13 were computed using the following formula:

cancer risk = cancer potency x lifetime dose

The lifetime doses for each type of exposure were computed as described in section 3. The cancer potencies used in the analysis are listed in table 4-1 and their derivation is described in the section 2 hazard analysis.

Cancer Risks to the Public

Results for acephate, carbaryl, malathion, diesel oil, and kerosene indicate that no member of the public is at a greater than 8.5 in 100 million risk of cancer from routine exposures. Accidental exposures resulting from a spill into a pond present a cancer of 3.2 in 1 million for carbaryl and 1.6 in 1 million or less for the other chemicals.

There are not sufficient data to characterize the carcinogenicity of B.t. in humans.

Cancer Risk to Workers

Cancer risks to workers for a 30-year work life at various tasks are presented in Table 4-14. Cancer risk for observer and card checker exposures to malathion exceed 1 in 1 million. Workers are not at cancer risk greater than 1 in 1 million for any other task or chemical. Cancer risks for worker accidents exceed 1 in 1 million for acephate and malathion spills on worker's skin (3.1 in 100,000 and 2.2 in 10,000, respectively) and for a broken hose accident involving malathion (4.7 in ten thousand) or acephate (1.6 in ten thousand). Accidental exposures assume the worker does not wash when the accident occurs. Normal precautions and immediate washing should reduce the actual cancer risk below 1 in 1 million.

Comparison of Cancer Risks With Other Common Risks

Table 4-15 presents cancer risks resulting from several familiar hazards and occupational risks. Motor vehicle accidents have a risk of fatality that averages 2 in 10,000 per person each year. Over a 30-year period, the cumulative risk would be 6 in 1,000. A variety of hazards that have an approximate risk at 1 in 1 million include smoking 2 cigarettes, eating 6 pounds of peanut butter, drinking 40 sodas sweetened with saccharin, or taking 1 transcontinental round trip by air. The cancer risk for a single x-ray is 7 in 1 million. Many occupational risks are greater. Working for 30 years in agriculture or construction has a risk of about 1.8 in 100, and in mining and quarrying, the risk is even greater: 3 in 100 over 30 years.

RISK OF HERITABLE MUTATIONS

No human studies are available that associate the insecticides in this analysis with heritable mutations. Furthermore, no risk assessments that quantify the probability of mutations from the insecticides are available in the literature or from EPA. Laboratory studies constitute the best available information on mutagenic potential. Results of the mutagenicity assays conducted on the three insecticides are summarized in table 2-4.

For some of the insecticides, no acceptable mutagenicity tests exist. For these insecticides, a worst-case assumption is made that these insecticides have the potential to cause mutations in humans. In these cases the results of carcinogenicity tests (see table 2-3) or cancer risk assessments can be used to estimate the worst case risk for mutagenicity. The rationale for this assumption is summarized by the USDA (1985) as follows:

> "Since mutagenicity and carcinogenicity both follow similar mechanistic steps (at least those that involve genetic toxicity), the calculated risk of cancer can be used as a worst-case approximation of somatic cell mutation risk. The basis for this assumption is that both mutagenicity and at least primary carcinogens react with DNA to form a mutation or DNA lesion affecting a particular gene or set of genes. The genetic lesions then require specific metabolic processes to occur, or the cells must divide to insert the lesion into the genetic code of the cell."

We believe the cancer risk provides a worst-case approximation to heritable mutations because:

1. All chemicals known to induce heritable germ cell mutation in mammals also produce cancer in mammals and almost always at a lower total dose.

2. Many chemicals that are carcinogens in rodents fail to induce heritable germ cell mutations even at the MTD.

3. Mammalian meiotic processes in gonadal tissue appear to be much more efficient in eliminating DNA lesions than somatic cells.

4. Human epidemiology studies of populations exposed to genotoxic carcinogens (radiation exposures in Nagasaki and Hiroshima) have demonstrated significant induction of cancer but no evidence of heritable mutations.

Malathion tested negative for mutagenicity in all but one assay conducted, and thus can be considered to pose no mutagenic risk. Carbaryl and acephate were nonmutagenic in the majority of assays conducted and were nononcogenic in all of the carcinogenicity tests performed; therefore, it can be assumed that their germ cell mutagenic risk is slight to negligible.

OTHER POSSIBLE EFFECTS OF THE INSECTICIDES

Synergistic Effects

Synergistic effects of chemicals are those that occur from exposure to two or more chemicals either simultaneously or within a relatively short period of time. For example, forestry workers exposed to the fungicide thiram have experienced skin blotching and nausea from drinking alcoholic beverages within 10 days of their thiram exposure. Synergism occurs when the combined effects of the two chemicals cannot be predicted based on the known toxic effects of the individual chemicals or when their combined effect is much greater than the sum of the effects of each agent alone. For example, a mixture of the herbicides 2,4-D and picloram has produced skin irritation in test animals while neither insecticide alone has been found to be a skin irritant. Cigarette smoke and asbestos are both known carcinogens. When inhaled in combination, they have been found to increase cancer risk eight fold above the risk of persons exposed to asbestos who do not smoke.

Evidence of Synergistic Effects From Pesticides

Instances of chemical combinations that cause synergistic effects are relatively rare. Kociba and Mullison (1985) in describing toxicological interactions with agricultural chemicals state the following:

> "Our present scientific knowledge in toxicology indicates that an exposure to a mixture of pesticides is more likely to lead to additivity or antagonism rather than synergism when considering the toxicological effects of such a combination. To be conservative and for reasons of safety, an

additive type of toxicological response is generally assumed rather than an antagonistic type of response.

In the case of registered pesticides, much toxicological information is developed during the research and development of each individual pesticide. In addition to this information on individual pesticides, short-term toxicity studies are always done prior to the selling of a pesticide mixture. Should synergism unexpectedly be present in a proposed commercial mixture of two pesticides, it would be identified in such cases and would then be dealt with accordingly. In toxicological tests involving a combination of commercial pesticides, synergism has generally not been observed."

The toxic effects of the possible insecticide combinations other than the EPA-registered commercial mixtures have not been studied. Time and money normally limit toxicity testing to the first priority--the effects of the insecticides individually--and this type of information is not yet sufficient in some cases. Moreover, the combinations that could be tested are too numerous to make that toxicity testing feasible. The combinations of interest in this risk assessment include not only combinations of two or more of the 3 insecticides, but also combinations of the insecticides with other chemicals, such as herbicides, that exist in the environment. Based on the limited amount of data available on pesticide combinations, it is possible but very unlikely that synergistic effects could occur as a result of exposure to two or more of the insecticides considered in this analysis.

Malathion, a relatively safe insecticide, has been observed to produce synergistic effects when combined with other organophosphorus insecticides. One incident of apparent poisoning from malathion in Pakistan sprayment indicates the possible synergistic effects of this pesticide (Baker et al., as cited in Doull et al., 1980). Data on specific organophosphorous pesticides that are synergistic with malathion have not been located (to date) in current literature.

Likelihood of Exposure to Two Insecticides

For several reasons, it is highly unlikely that synergistic adverse effects could result from exposure to more than one insecticide applied in separate projects. First, unlike the situation in conventional agriculture, insecticide residues in plants and soil are not expected to persist from one application to another, even for the more persistent insecticides. Also, the probability of more than one insecticide being used in any year is remote.

Second, the 3 insecticides are known to be rapidly excreted from the body. None of the insecticides has been found to accumulate in test animal body tissues, so exposure of an individual to two insecticides at different times would be unlikely to cause simultaneous residues within the body.

Third, public exposures to the insecticides should be low (except for accidents) and should occur only very infrequently. The probability of a larger accidental exposure to any single insecticide is extremely low. Because the probability of a member of the public receiving a large exposure is so low for one insecticide, the probability of simultaneous large exposures to two insecticides is negligible. This is because the probability of two independent

events occurring simultaneously is the product of the probabilities of the individual events. For example, if the probability of a person receiving a given exposure is 1 in 1,000 for each of 2 insecticides, then the probability of receiving that exposure to both insecticides would be 1 in 1 million.

Risks From Insecticide Mixtures

Simultaneous exposure to more than one chemical is likely in cases where those chemicals are combined in a single spray mixture. Although most spruce budworm control projects in the Region would involve only a single insecticide, some areas would be treated with a mixture of insecticides, but only EPA-approved mixtures would be used.

The EPA guidelines for assessing the risk from exposures to chemical mixtures (EPA, 1986a) recommend using additivity models when little information exists on the toxicity of the mixture and when components of the mixture appear to induce the same toxic effect by the same mode of action. They suggest in their discussion of interactions (synergistic or antagonistic effects) of chemical mixtures that "there seems to be a consensus that for public health concerns regarding causative (toxic) agents, the additive model is more appropriate than any multiplicative model."

Table 4-16 shows margins of safety for the mixture used in spruce budworm suppression that ismost likely to cause additive effects--the combination of diesel oil and kerosene used in carbaryl applications. The table indicates that, except for worst-case drift exposures (MOS = 76), all MOS's for systemic and reproductive effects are greater than 100. Some systemic effects may be seen in worker Ecological Evaluation (EE) Team members in typical exposures and in observers, card checkers, and EE Team members in worst-case exposures. No workers should experience reproductive effects. Workers and members of the public may experience both systemic and reproductive effects from accidents.

Although the insecticides used for spruce budworm control are unlikely to have synergistic toxic effects, other substances occurring in the diets of exposed people may have some influence on the toxicity of the insecticides.

Effects on Sensitive Individuals

If the response of a population of test animals to varying doses of a chemical follows a normal distribution (bell-shaped curve), the hypersensitive individuals are those on the left-hand side of the curve that respond at much lower doses than the average. A safety factor of 10 has traditionally been used by regulatory agencies (NAS, 1977) to account for this intraspecies (that is, interindividual) variation. Not all sensitive individuals will be covered by an MOS of 100, because human susceptibility to toxic substances can vary two or three orders of magnitude (Calabrese, 1985). (These individuals could correspond to the very tail of the bell-shaped curve.)

Factors Affecting the Sensitivity of Individuals

Factors that may affect individual susceptibility to toxic substances include diet, age, heredity, preexisting diseases, and life style (Calabrese, 1978). These factors have been studied in detail for very few cases, and their significance in controlling the toxicity of the proposed insecticides is

unknown. However, enough data have been collected on other chemicals to show that these factors can be important.

Elements of the diet known to affect toxicity include vitamins and minerals (Calabrese and Dorsey, 1984). For example, the mineral selenium can prevent the destruction of blood-forming tissues by chronic heavy exposure to benzene. Large doses of vitamin C have also been shown to protect animals and humans from toxic effects of chronic benzene exposure. Vitamin A seems to have a preventative effect on cancer induced by chemicals such as benzo(a)pyrene (found in cigarette and wood smoke) and DMBA. This effect has been seen in laboratory animals and human epidemiological studies. The food additives BHT and BHA also may be active in preventing the carcinogenicity of benzo(l)pyrene. Various levels of the B vitamin riboflavin have also been tested with mixed results. Vitamin C has been shown to prevent nitrites from combining with amines to form nitrosamines, and vitamin E seems to be at least as effective. These vitamins would be likely to prevent the formation of N-nitrosoatrazine and N-nitrosoglyphosate if conditions were otherwise favorable for their formation in the human stomach (Calabrese and Dorsey, 1984).

Genetic factors are also known in some cases to be important determinants of susceptibility to toxic environmental agents (Calabrese, 1984). Susceptibility to irritants and allergic sensitivity vary widely among individuals and are known to be largely dependent on genetic factors. Race has been shown to be a significant factor influencing sensitivity to irritants, and some investigations have indicated that women may be more sensitive than men (Calabrese, 1984).

A variety of human genetic conditions have been identified as possibly enhancing susceptibility to environmental agents. For example, persons with beta thalassenia may be at increased risk when exposed chronically to benzene. However, only one condition, G-6-PD deficiency, has been conclusively demonstrated to cause enhanced susceptibility to industrial pollutants. Several other genetic conditions have been shown to involve defects in the cellular mechanisms for repair of damage to DNA. Persons with these diseases share an increased sensitivity to the effects of ultraviolet light, which can cause cancer. Cells from individuals with at least one of these diseases, xeroderma pigmentosum, also are sensitive to a variety of chemical substances implicated as causative agents of human cancers (Calabrese, 1984).

Persons with other types of preexisting medical conditions may also be at increased risk of toxic effects. For example, sensitivity to chemical skin irritants can be expected to be greater for people with a variety of chronic skin ailments. Individuals who are immunosuppressed due to illness or from therapeutic treatment may be susceptible to microbial agents not known to be infectious to normal individuals. Patients with these conditions may be advised to avoid occupational exposure to irritating chemicals or B.t. (Shmunes, 1980, as cited in Calabrese, 1984).

Allergic Hypersensitivity

A particular form of sensitivity reaction to a foreign substance is allergic hypersensitivity. Except for contact dermatitis in delayed allergic reations, these are responses to high molecular weight organic molecules or whole cells.

None of the insecticides in the Forest Service spruce budworm suppression program is of high molecular weight, so the immediate allergic reactions and the delayed allergic reactions, except for contact dermatitis, can be ruled out as possible toxic effects. Contact dermatitis may be induced by lower molecular weight substances, such as the catechols of poison ivy, cosmetics, drugs, or antibiotics (Volk and Wheeler, 1983). Benzocaine, neomycin, formaldehyde, nickel, chromium, and thiram are all known to produce these reactions (Marzulli and Maibach, 1983).

A series of dermal sensitization studies showed no evidence that B.t. could induce allergic hypersensitivity (Fisher and Rosner, 1959 as cited in Sassaman, 1987).

Likelihood of Effects in Sensitive Individuals

Based on the current state of knowledge, individual susceptibility to the toxic effects of the insecticides cannot be specifically predicted. As discussed above, safety factors have traditionally been used to account for variations in susceptibility among people. The margin-of-safety approach used in this risk assessment takes into account much of the variation in human response, as discussed earlier by Calabrese (1985). As described in the introduction to this risk assessment, a safety factor of 10 is used for interspecies variation; an additional safety factor of 10 is used for within-species variation.

Thus, the normal margin of safety of 100 for both types of variation is sufficient to ensure that most people will experience no toxic effects. However, unusually sensitive individuals may experience effects even when the margin of safety is equal to or greater than 100.

Some people may develop contact dermatitis from insecticide exposure. However, the small, infrequent exposures of the public should limit the possibility of their experiencing this type of reaction.

Effects from Inert Ingredients in Insecticide Formulations

Inert ingredients are chemicals that are added to the active ingredient to prepare a pesticide formulation. Inert ingredients provide a carrier for the active ingredient that facilitates the effective application of the pesticide but that is not intended to supplement the pesticide's toxic properties.

This risk assessment characterizes human health risks by comparing estimated insecticide doses with toxicity levels found in laboratory animal studies. The estimated doses and laboratory hazard levels are based on the active ingredients of the proposed insecticides, not on the formulated products. This is reasonable because the active ingredients possess the intended pesticidal properties. However, consideration of the possible toxic properties of the remaining portion of the formulations, the inert ingredients, is also warranted as is the possibility of synergism from the combination of active and inert ingredients in the formulations.

Toxicity of the Inert Ingredients

For the toxicity of the inert ingredients alone, EPA's Office of Pesticide programs (EPA, 1986b) has identified about 1,200 inert ingredients used in

approved pesticides and has reviewed the available evidence concerning their toxicity. The data included laboratory toxicity tests, epidemiological data, and structure/activity relationships. A particular concern in reviewing the inerts was their potential for causing chronic human health effects. On completion of its review, EPA categorized the 1,200 inerts into the following four lists.

- List 1 contains about 55 inerts that have been shown to be carcinogens, developmental toxicants, neurotoxins, or potential ecological hazards that merit the highest priority for regulatory action. EPA is requesting manufacturers to replace these inerts in their formulations with less toxic chemicals.

- List 2 contains approximately 50 chemicals that have been given high priority for testing because of available toxicity data that are suggestive, but not conclusive, of possible chronic health effects or because they have structures similar to chemicals on List 1.

- List 3 contains approximately 800 chemicals that are of lower priority for testing because neither available toxicity data nor a review of their chemical structure shows evidence that would place them in Lists 1 or 2.

- List 4 of about 300 chemicals contains those inerts generally recognized as safe. It includes substances such as corn oil, honey, peanut oil, and water.

Because EPA normally classified inert ingredients as "Confidential Business Information," information on them does not have to be released to the public under the Freedom of Information Act (see also 40 CFR 1506.(a)). Nonetheless, the Forest Service requested that EPA review each of the formulations of the three insecticides proposed for use and disclose whether any of them contained inert ingredients of, or suggestive of, toxicological concern.

Kerosene, a petroleum distillate (a carbaryl inert), is present on EPA's List 2. A risk analysis was performed on diesel oil used as a carbaryl carrier and kerosene.

Toxicity of the Formulations

With respect to the possibility of synergism in the formulated combination of active and inert ingredients, EPA generally requires only acute toxicity data on formulated products. These data also allow EPA to address concerns about the acute toxicity of the pesticide formulations' inert ingredients. However, none of the insecticide formulations proposed for use by the Forest Service have undergone chronic toxicity testing, including cancer testing, or any reproductive, developmental, or mutagenicity testing. The inert ingredients in the proposed formulated products might cause cancer or other long-term health effects. Given the little information that is available on each insecticide's formulation, the possibility that the formulated product is more toxic than the active ingredient cannot be discounted entirely. EPA (1986a) suggests that in the absence of data, additive effects should be assumed. Therefore, this analysis does not assume that the insecticides are synergistic with inert ingredients in their formulations.

Cumulative Effects

The total area of U.S. Forest Service land in Washington and Oregon and BLM land in western Oregon is 38,000 square miles. This area makes up about one-fourth of the total land area (165,000 square miles) of those two states. In a given year, the Forest Service may treat up to approximately 1,350 square miles (850,000 acres) with insecticides for budworm suppression. The treated area would thus comprise less than 1 percent of the total land area of the two States. Moreover, the treatments would occur for the most part in the remote areas of these densely forested lands. In general, treatment units are sprayed only once in a given year, then not treated again until a number of years later. The later treatment also may be with a different insecticide.

No individual member of the public is likely to receive repeated exposures to any of the insecticides because of the remoteness of most treatment units, the widely spaced timing of repeated treatments, and the use of a variety of insecticides for different purposes. In addition, the precautions taken by the Forest Service in their treatment operations make any dose at all to the public unlikely.

Populations at Risk

The populations at risk in insecticide spraying operations in the Pacific Northwest fall into three categories: (1) workers involved in the spray operations, (2) forest users, such as hikers, hunters, and fishermen, and (3) residents of dwellings in and near the forest.

The number of workers involved in spraying operations for a typical spray year for the Forest Service is discussed in section 3. The number of forest visitors to Forest Service and BLM land is recorded as visitor days by the agencies. The Forest Service in Region 6 averages approximately 30 million total visitor days annually. The number of residents living within one-quarter of a mile of Forest Service land is 29,831 and within one-half of a mile is 50,919.

Again, because of the remote locations of most insecticide application sites, no member of the public should be exposed during most operations.

WILDLIFE RISK ANALYSIS

Wildlife species risk from spruce budworm suppression with insecticides is a function of the inherent toxicity (hazard) of each insecticide to different organisms and of the amount of each chemical (exposure) those organisms may take in as a result of a spraying operation. The wildlife species risk analysis compares estimated acute exposures of representative species determined in the previous section with acute toxicity levels found in laboratory studies.

Wildlife Risk Analysis Criteria

For wildlife risks, the criteria used by EPA in ecological risk assessment (EPA, 1986c) were used to judge the absolute risks to the different

representative species and the relative risks among the five chemicals. The EPA criteria call for comparison of an estimated environmental concentration (EEC) with a laboratory-determined LD_{50} or LC_{50} for the most closely related laboratory test species.

The EEC exceeds 1/5 LD_{50} or LC_{50}, EPA deems it a significant risk that may be mitigated by restricting use of the pesticide. EPA judges EEC's that exceed the LD_{50} or LC_{50} as unacceptable risk levels. Doses below the 1/5 LD_{50} level are assumed to present a low risk. In this risk assessment, an organism's total estimated dose (rather than an EEC) is compared with the laboratory toxicity level because the dose comes from all exposure routes, not just feeding.

Analysis of insecticide risk to wildlife compared estimated acute doses for the representative wildlife species with available hazard information on the most closely related species. Because the insecticides examined in this appendix show no tendency to bioaccumulate, long-term persistence in food chains and subsequent toxic effects, such as those that have resulted from the use of the persistent organochlorides, are not considered a problem and are not examined in the risk analysis. No analysis of chronic wildlife dosing was done because the insecticides degrade relatively rapidly and sites are normally treated only once per year.

Wildlife toxicity reference levels used to assess the risks of the insecticides are given in tables 4-17 through 4-21.

Wildlife Exposure Analysis

Tables 4-17 through 4-21 give the total typical and worst-case estimates for the 14 representative wildlife species for each of the spruce budworm insecticides being evaluated for Region 6.

The wildlife risk assessment tends to overstate the risks because many of the assumptions are quite conservative. For example, no degradation of the herbicides is assumed to occur and all herbicide sprayed is assumed to be biologically available. In the extreme exposures, the entire diet of an animal is assumed to consist of contaminated items, while in the realistic case, a significant percentage of the diet is assumed to be contaminated. Dermal exposures are assumed to come both directly from herbicide spray and indirectly from brushing up against treated vegetation. Birds and mammals are assumed to receive dermal doses through their skin and from grooming. This accumulation of doses from every route undoubtedly overestimates doses, even in the realistic case. Nevertheless, when these dose estimates do exceed the EPA risk criterion, and more so when they exceed the LD_{50} for the most closely related laboratory species, there is a clear risk of adverse effects on individual animals.

B.t. Risk to Nontarget Organisms

Wildlife and aquatic species are not at risk from B.t. applications. Available studies indicate that B.t. is relatively nontoxic to all vertebrate forms. Nontarget insects are at risk. The delta-endotoxin produced by B.t. is toxic to larvae of lepidopteran insects (butterflies and moths), coleopterans (beetles), and to some dipterans (flies and mosquitoes). Certain species such

as the cinnabar moth, which is used as a control of tansy ragwort, may be affected by B.t. application. Other desirable species, such as rare butterflies also could be affected. The U.S. Fish and Wildlife Service identifies endagered and threatened species of invertebrates and the Forest Service would cooperate to mitigate the effects of B.t. applications on endangered or threatened lepidopteran.

Wildlife Risk Overview

In general, based on the available toxicity data and on the proposed application rates, the risks to wildlife from the use of the three insecticides and diesel oil and kerosene are low to negligible in the spruce budworm suppression program. Except for small mammals and the smaller birds, realistic doses seldom exceed 10 mg/kg for any of the insecticides. The realistic dose estimates are well below the EPA risk criterion of 1/5 LD_{50} and are far below the laboratory species LD_{50} for most of the species.

Local populations of small mammals, small birds, amphibians, and reptiles may be adversely affected when large areas are treated; however, the reproductive capacity of these species is generally high enough to replace the few lost individuals within the next breeding cycle. Populations of larger mammals and birds and any domestic animals present are not likely to be affected at all.

The risks of the individual insecticides are discussed below. Literature references for the toxicity levels in laboratory species are given in the wildlife hazard analysis. Again, it must be noted that there are very few toxicity studies on which to base these conclusions. However, the conservatism used in estimating the wildlife doses should compensate for much of the uncertainty in the toxicity data base.

The risks to wildlife of the individual chemicals used in spruce budworm suppression can be judged by examination of Tables 4-17 through 4-21.

Acephate. None of the realistic doses of acephate for any representative species exceeds the EPA risk criterion level of 1/5 the LD_{50}. The extreme dose to the mouse does exceed the EPA risk level; therefore, small mammals directly sprayed may be at risk from the use of acephate. No other wildlife or domestic species should be affected.

Carbaryl. None of the realistic or extreme wildlife doses of carbaryl exceed the EPA risk criterion of 1/5 LD_{50}, so wildlife are not at risk from carbaryl in this program.

Malathion. Only the extreme malathion dose to the rabbit exceeds the EPA criterion, although the bird, mouse, and reptile and amphibian doses approach the 1/5 LD_{50} levels, so there is some low level of risk to wildlife from the use of malathion.

Diesel Oil and Kerosene. Wildlife exposures are far below the EPA risk levels for these two chemicals, so they present no risk to wildlife in this program.

Risk to bird eggs and nestlings

To any bird eggs or nestlings exposed to the three insecticides or diesel oil and kerosene, some risk of death or injury is present. Risks would be greatest for the use of acephate and malathion, considering their possible effects on mature birds, as indicated in Tables 4-17 and 4-19. The nestlings would get a dermal dose depending on how well protected the nest was and an oral dose depending on the amount of residues on their food items. Bird eggs are far less likely to be affected by the insecticides because they are not likely to be left uncovered during a spray operation. The parents' body would protect the eggs from direct deposition, although a minor amount of insecticide might reach the egg by way of the feathers of either incubating parent. Diesel oil and kerosene do present some risk to bird eggs because they penetrate the shell more easily than the water-based insecticides and are relatively toxic to developing embryos. Here again, the eggs are not likely to receive any appreciable amount of these chemicals because the eggs are normally protected by an incubating adult.

AQUATIC RISK ANALYSIS

The risks of adverse effects from exposure to the insecticides that drift offsite and accidents were estimated for the representative aquatic species described previously. Acute toxicity reference values (LC_{50}'s or EC_{50}'s) used in the analysis were selected for the representative species from Table 2-6 in the aquatic hazard analysis section 2.

In cases where no acute toxicity reference value was available for a representative species, a value was selected from Table 2-6 using the value of the most closely related species. For fish species, preference was given to toxicity values of other species within the same genus or family. If no toxicity values were available for any member of that family, then the lowest value reported for any fish species was used.

To estimate the risk of adverse effects occuring, the selected toxicity reference values were compared to the typical and worst case estimated environmental concentrations of each insecticide for a body of water 0.61 meter (2-feet) deep. The ratio of the EEC to the LC_{50} (or EC_{50}) is called the quotient value (Q-value). Typical EEC's were based on typical application rates and a distance of 153 meters (500 feet) from the application site to the body of water. Worst-case EEC's were calculated using maximum application rates and a distance of 30.5 meters (100 feet) to a body of water. EEC's for petroleum distillates were based on the fraction of kerosene in carbaryl formulations and the amount of diesel oil used as a carrier. The Q-values were compared to the risk criteria proposed by EPA (1986a) where the risks of adverse effects to fish or invertebrates are estimated as follows:

Q-value	Risk
$EEC/LC_{50} < 0.1$	No acute risk
$EEC/LC_{50} \geq 0.1$ and	Presumption of risk that may be mitigated
$EEC/LC_{50} < 0.5$	

$EEC/LC_{50} \geq 0.5$	Presumption of significant risk of acute effects
EEC < NOEL or MATC	No chronic risk

Results of the Risk Analysis

Acute Toxicity

The results of the risk analysis indicate that there is no significant risk of acute adverse effects to any of the representative aquatic species for typical and worst case exposures resulting from drift (see Tables 4-22 to 4-25). All Q-values are less than 0.1. Aquatic invertebrates are at slight risk of adverse effects from malathion under worst-case conditions.

The acute risks to some groups of aquatic invertebrates could not be estimated for some of the chemicals because sufficient toxicity information was not available (see Table 4-26).

Based on the most conservative acute toxicity value, aquatic organisms are at slight risk from the petroleum distillates (kerosene and diesel oil combined) under typical conditions. Under worst-case conditions, aquatic organisms are at significant risk of adverse effects from petroleum distillates (see Table 4-25).

Chronic Toxicity

Very limited information is available on the chronic toxicity of these insecticides to aquatic species. In the absence of chronic toxicity information, the likelihood of long-term exposure to insecticide residues was evaluated. The fraction of initial insecticide residue remaining in water was calculated for 1, 2, and 3 weeks after insecticide application using insecticide degradation rates reported in the literature (see appendix A). The results are given in Table 4-27. Less than 10 percent of the initial residue remains at 3 weeks for carbaryl, malathion, and petroleum distillates. Residues of approximately 73 percent of the initial acephate residue remain at 3 weeks. In streams and other lotic (flowing) waters, insecticide concentrations would quickly be reduced by dilution and transport; however, chronic exposure could occur in ponds and lakes from acephate, which degrades slowly. For typical conditions, the EEC for acephate is at least 500 times less than the lowest acute toxicity value (LC_{50} or EC_{50}) reported. It is unlikely that chronic effects would result from these estimated concentrations when there is such a large margin of safety for acute effects.

Accidents

EEC's were calculated for a spill of a helicopter load of 758 liters (200 gallons) of insecticide mixture into a 1-acre pond.

Fish are not expected to experience adverse acute effects from spills of acephate or carbaryl (see Tables 4-28 and 4-29). However, some species of aquatic invertebrates are likely to be killed or suffer severe acute effects.

A spill of a helicopter load of malathion into a small pond would likely cause invertebrate species to be killed (see Table 4-30). Estimated concentrations are approximately 1,000 times greater than the LC_{50}'s of stoneflies and scuds. Some fish species, such as bluegill, may be at significant risk of acute effects, and other fish species are at slight risk (see Table 4-30).

A spill of diesel oil and kerosene into a 1-acre pond could likely result in a severe kill of fish and aquatic invertebrates (see Table 4-31).

Estimated insecticide concentrations in a pond that is accidentally directly sprayed at worst-case application rates are less than those estimated for the pond spill. No significant adverse effects are expected from direct spraying of a pond at worst-case rates for acephate, carbaryl, or malathion (see Tables 4-28-4-30). Invertebrates are at slight risk from direct spraying of malathion. Aquatic organisms are at significant risk of acute adverse effects from direct spraying of petroleum distillates (see Table 4-31).

Table 4-1--Toxicity reference levels used in the analysis of human health risks

Chemical	Rat oral LD_{50}(mg/kg)	Systemic NOEL (mg/kg/day)	Reproduction development NOEL (mg/kg/day)	Cancer potency
Acephate	866	0.25	3	0.0093[a]
Carbaryl	270	1.8	2	0.076[b]
Malathion	370	0.2	25	0.02[c]
Diesel oil	7,380	7.38	751	0.0000049
Kerosene	28,000	28	751	0.0000049
<u>Bacillus</u> <u>thuringiensis</u>				
Inhalation	---	1.4	---	---
Oral	---	500	---	---

[a]EPA, 1985.

[b]Assuming 1 percent of ingested carbaryl is converted to N-nitrosocarbaryl in the stomach (Lijinsky and Taylor, 1986).

[c]California Department of Health Services (1980).

Table 4-2--Summary of spruce budworm insecticide margins of safety for the public for typical exposures.

Chemical	MOS'S for systemic effects	MOS's for reproductive effects
Acephate	MOS's less than 100 for drift (85), eating peas and beans (64), and for the hunter (86)	All greater than 100
Carbaryl	All greater than 100	All greater than 100
Malathion	MOS's less than 100 for drift (53), eating peas or beans (28), eating berries (57), and for the hunter (39)	All greater than 100
Diesel oil	All greater than 100	All greater than 100
Kerosene	All greater than 100	All greater than 100
B. thuringiensis	All greater than 100	___

Table 4-3--Summary of spruce budworm insecticide margins of safety for the public routine-worst case exposures.

Chemical	MOS's for systemic effects	MOS's for reproductive effects
Acephate	MOS's less than 100 for drift (28), eating fish (64), peas or beans (25), berries (48), and for the fisherman (44) and hunter (33)	All greataer than 100
Carbaryl	All greater than 100	All greater than 100
Malathion	MOS's less than 100 for drift (16), drinking water (64), eating peas or beans (10), eating berries (19), and for the fisherman (48) and hunter (13)	All greater than 100
Diesel oil	All greater than 100 except for drift (98)	All greater than 100
Kerosene	All greater than 100	All greater than 100
B. thuringiensis	All greater than 100	___

Table 4.3b Estimated daily dose (mg/kg/day) of insecticides to humans from drinking contaminated water and margin of safety.

Pesticide	Subarea	Human Dose (mg/kg/day	NOEL	Margin-of-Safety In Runoff
Acephate	A	0.000711	0.25	352
	B	0.000649	0.25	385
	C	0.000711	0.25	352
	Reservoir	0.000103	0.25	2,417
Malathion	A	0.000466	0.2	429
	B	0.000626	0.2	319
	C	0.000991	0.2	202
	Reservoir	0.000104	0.2	1,923
Carbaryl	A	0.0041	1.8	439
	B	0.00382	1.8	471
	C	0.0035	1.8	514
	Reservoir	0.00057	1.8	3,159

Table 4.3c Doses and margins of safety for humans consuming crops grown with contaminated irrigation water.

Insecticide	Dose	MOS
Acephate	0.000277	903
Carbaryl	0.000091	19,740
Malathion	0.00126	159
Diesel	0.00150	4,930
Kerosene	0.00043	65,116

Table 4-4--Acephate margins of safety

	Systemic		Reproductive	
	Typical exposures	Worst case exposures	Typical exposures	Worst Case exposures
Public				
Dermal				
Veg. contact	1,200	1,200	10,000	10,000
Dermal & inhalation				
Drift	85	28	1,023.5	333.3
Dietary				
Water	500	160	5,992.7	1,931.4
Fish	200	64	2,397.1	772.6
Meat	1,100	360	10,000	4,268.3
Peas or beans	64	25	766.9	301.3
Berries	130	48	1,533.8	576.9
Cumulative				
Fisherman	130	44	1,526.1	531
Hunter	86	33	1,035.6	391.1
Workers				
Pilot	300	150	3,563.5	1,851.4
Mixer/loader	130	51	1,608.5	631
Observer	85	28	1,023.5	333.3
Card checker	70	23	839.6	413.8
E.E. team	10,000	10,000	10,000	10,000
Backpack	29.0	6.1	349.9	72.8
Accidents				
Spill onto worker		-340.0[a]		-28.6[a]
Broken hose		-170.0[a]		-14.3[a]
Direct spray - adult		17.0		201.4
Direct spray - child		11.0		134.4
Peas or beans		15.0		177.2
Spill into water				
200 gallons into pond		-4.2[a]		2.9

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 0.25 and a reproductive NOEL of 3.

[a]When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

Table 4-5--Carbaryl margins of safety.

	Systemic		Reproductive	
	Typical exposures	Worst case exposures	Typical exposures	Worst Case exposures
		Public		
Dermal				
Veg. contact	10,000	8,300	10,000	9,174.8
Dermal & inhalation				
Drift	1,200	200	1,312.1	217.8
Dietary				
Water	6,900	1,100	7,683	1,262.3
Fish	10,000	4,500	10,000	5,049.4
Meat	10,000	2,500	10,000	2,789.8
Peas or beans	880	180	983.2	196.9
Berries	1,800	340	1,966.4	377.1
Cumulative				
Fisherman	4,100	820	4,581.6	909.7
Hunter	1,200	230	1,327.7	255.6
		Workers		
Pilot	4,100	1,100	4,568.6	1,210.1
Mixer/loader	1,900	360	2,062.2	400.6
Observer	1,200	200	1,312.1	217.8
Card checker	920	230	1,017.8	258.6
E.E. team	3,800	500	3,239.9	551.5
Backpack	400	43	448.6	47.6
		Accidents		
Spill onto worker		-95.0[a]		-85.7[a]
Broken hose		-24.0[a]		-21.9[a]
Direct spray - adult		120.0		131.6
Direct spray - child		79.0		87.8
Peas or beans		100.0		115.8
Spill into water				
200 gallons into pond		1.7		1.9

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 1.8 and a reproductaive NOEL of 2.

[a]When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

Table 4-6--Malathion margins of safety.

	Systemic		Reproductive	
	Typical exposures	Worst case exposures	Typical exposures	Worst case exposures
		Public		
Dermal				
Veg. contact	740	670	10,000	10,000
Dermal & inhalation				
Drift	53	16	6,685.7	1,967.9
Dietary				
Water	220	64	10,000	8,047.5
Fish	890	260	10,000	10,000
Meat	510	150	10,000	10,000
Peas or beans	28	10	3,550.5	1,255.4
Berries	57	19	7,101	2,403.8
Cumulative				
Fisherman	140	48	10,000	5,977.4
Hunter	39	13	4,919.8	1,654.6
		Workers		
Pilot	190	87	10,000	10,000
Mixer/loader	84	29	10,000	3,621.6
Observer	53	16	6,685.7	1,967.9
Card checker	42	19	5,229.5	2,347.6
E.E. team	78	23	9,743	2,929.5
Backpack	19	3.5	2,314.4	433.3
		Accidents		
Spill onto worker		-1,400.0[a]		-11.2[a]
Broken hose		-300.0[a]		-2.4[a]
Direct spray - adult		9.6		1,198.8
Direct spray - child		6.4		799.2
Peas or beans		5.9		738.5
Spill into water				
200 gallons into pond		-11.0[a]		11.9

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of .2 and a reproductive NOEL of 25.

[a]When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

Table 4-7--Diesel oil margins of safety.

	Systemic		Reproductive	
	Typical exposures	Worst case exposures	Typical exposures	Worst case exposures
Public				
Dermal				
Veg. contact	8,100	4,100	10,000	10,000
Dermal & inhalation				
Drift	600	98	10,000	9,928.1
Dietary				
Water	8,700	1,400	10,000	10,000.0
Fish	2,700	430	10,000	10,000
Meat	10,000	2,300	10,000	10,000
Peas or beans	1,100	220	10,000	10,000
Berries	2,200	420	10,000	10,000
Cumulative				
Fisherman	1,600	300	10,000	10,000
Hunter	1,300	260	10,000	10,000
Workers				
Pilot	2,100.0	550.0	10,000.0	10,000.0
Mixer/loader	950.0	180.0	10,000.0	10,000.0
Observer	600.0	98.0	10,000.0	9,928.1
Card checker	450.0	110.0	10,000.0	10,000.0
E.E. team	75.0	28.0	7,669.5	2,876.1
Backpack	200.0	21.0	10,000.0	2,143.6
Accidents				
Spill onto worker		-99.0[a]		1.0
Broken hose		-49.0[a]		2.1
Direct spray - adult		58.0		5,931.3
Direct spray - child		39.0		3,954.2
Peas or beans		130.0		10,000.0
Spill into water				
200 gallons into pond		2.1		209.9

Note: ~Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 7.38 and a reproductive NOEL of 751.

[a]When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

Table 4-8--Kerosene margins of safety.

	Systemic		Reproductive	
	Typical exposures	Worst case exposures	Typical exposures	Worse case exposures
Public				
Dermal				
Veg. contact	10,000.0	10,000.0	10,000.0	10,000.0
Dermal & inhalation				
Drift	8,100.0	1,300.0	10,000.0	10,000.0
Dietary				
Water	10,000.0	10,000.0	10,000.0	10,000.0
Fish	10,000.0	5,700.0	10,000.0	10,000.0
Meat	10,000.0	10,000.0	10,000.0	10,000.0
Peas or beans	10,000.0	2,900.0	10,000.0	10,000.0
Berries	10,000.0	5,500.0	10,000.0	10,000.0
Cumulative				
Fisherman	10,000.0	4,000.0	10,000.0	10,000.0
Hunter	10,000.0	3,500.0	10,000.0	10,000.0
Workers				
Pilot	10,000.0	7,200.0	10,000.0	10,000.0
Mixer/loader	10,000.0	2,400.0	10,000.0	10,000.0
Observer	8,100.0	1,300.0	10,000.0	10,000.0
Card checker	6,100.0	1,500.0	10,000.0	10,000.0
E.E. team	1,000.0	370.0	10,000.0	9,978.2
Backpack	2,700.0	280.0	10,000.0	7,437.1
Accidents				
Spill onto worker		-26.0[a]		1.0
Broken hose		-3.7[a]		7.2
Direct spray - adult		770.0		10,000.0
Direct spray - child		510.0		10,000.0
Peas or beans		1,700.0		10,000.0
Spill into water				
200 gallons into pond		27.0		728.3

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 28 and a reproductive NOEL of 751.

[a]When the exposure exceeded the NOEL, the MOS ratio was reversed and a minus sign added.

Table 4-9--B.t. Margins of Safety.

	Typical	Worst Case
Public		
Inhalation[a] (Drift)	5,102	1,904
Dietary[b]		
Water	303,030	73,206
Peas or beans	38,730	11,413
Berries	77,519	21,853
Cumulative		
Hunter	61,652	16,829
Workers		
Pilot[a]	11,904	6,211
Mixer/loader[a]	8,403	3,861
Observer[a]	5,102	1,904
Accidents		
Peas or beans		6,711
Spill into pond		108

[a]Based on 1.4 mg/kg/day for human volunteer inhalation.

[b]Based on 500 mg/kg/day for rats feeding on 1 percent Biotrol in their diets.

Table 4-10--Margins of safety for the public in accidents.

Chemical	Adult sprayed	Child sprayed	Eat from sprayed garden	Drink water from pond spill
Acephate	17	11	14.8	-4.2
Carbaryl	120	79	107	1.7
Malathion	9.6	6.3	5.9	-11
Diesel oil	58	38	130	2.1
Kerosene	770	508	1,720	27

Table 4-11--Summary of spruce budworm insecticide margins of safety for workers in routine-typical exposures.

Chemical	MOS's for systemic effects	MOS's for reproductive effects
Acephate	MOS's less than 100 for observer (85), card checker (35), and backpack sprayer (29).	All greater than 100
Carbaryl	All greater than 100	All greater than 100
Malalthion	MOS's less than 100 for mixer/ loader (84), observer (53), card checker (21), E.E. Team (78), and backpack sprayer (19).	All greater than 100
Diesel oil	MOS less than 100 for E.E. Team (75).	All greater than 100
Kerosene	All greater than 100	All greater than 100

Table 4-12--Summary of spruce budworm insecticide margins of safety for workers in routine-worst case exposures.

Chemical	MOS's for systemic effects	MOS's for reproductive effects
Acephate	MOS's less than 100 for mixer/loader (51), observer (28), card checker (34), and backpack spryaer (6.1).	MOS less than 100 for backsprayer (72.8).
Carbaryl	MOS less than 100 for backpack sprayers (43).	MOS less than 100 for backpack sprayer (47.6).
Malathion	MOS's less than 100 for pilot (87), mixer/loader (29), observer (16), card checker (19), E.E. t eam (23), and backpack sprayer (3.5).	All greater than 100
Diesel oil	MOS's less than 100 for observer (98), E.E. team (28), and backpack sprayer (21).	All greater than 100
Kerosene	All greater than 100	All greater than 100

Table 4-13--Worker risk from accidents.

Chemical	Spill on worker Systemic	Spill on worker Repro.	Broken hose Systemic	Broken hose Repro.	Accidental spray Systemic	Accidental spray Repro.
Acephate	-340	-28.6	-8.6	1.4	17	201.4
Carbaryl	-95	-85.7	-1.2	-1.1	120	131.6
Malathion	-1,400	-11.2	-15	8.3	9.6	1,198.8
Diesel oil	-99	1.0	-2.5	41.2	58.0	5,931.3
Kerosene	-26	1.0	5.3	143	770	10,000

Table 4-14--Lifetime cancer risk.

	Acephate	Carbaryl	Malathion	Diesel	Kerosene
Public					
Dermal & inhalation					
Drift	1.3E-08	No Risk	3.6E-08	3.6E-11	1.0E-11
Dietary					
Water	2.2E-09	1.2E-06	8.8E-09	2.5E-12	7.1E-13
Fish	5.5E-09	2.9E-07	2.2E-09	8.1E-12	2.3E-12
Meat	1.0E-09	5.3E-07	3.8E-09	1.4E-12	4.1E-13
Peas or beans	1.6E-08	8.5E-06	6.5E-08	1.8E-11	5.1E-12
Berries	8.3E-09	4.3E-06	3.3E.08	9.1E-12	2.6E-12
Cumulative					
Fisherman	8.5E-09	1.5E-06	1.3E-08	1.2E-11	3.5E-12
Hunter	1.2E-08	6.0E-06	4.8E-08	1.5E-11	4.3E-12
Workers					
Pilot	9.0E-08	No Risk	2.5E-07	2.4E-10	6.9E-11
Mixer/loader	2.2E-07	No Risk	6.1E-07	6.2E-10	1.8E-10
Observer	4.SE-07	No Risk	1.3E-06	1.3E-09	3.7E-10
Card checker	1.0E-06	No Risk	2.9E-06	2.8E-09	7.9E-10
E.E. team	2.6E-11	No Risk	6.9E-07	6.0E-09	1.7E-09
Accidents					
Spill onto worker	3.1E-05	No Risk	2.2E-04	1.4E-07	1.4E-07
Broken hose	7.8E-07	No Risk	2.3E-06	3.5E-09	1.0E-09
Accidental spray	5.4E-09	No Risk	1.6E-08	2.4E-11	7.0E-12
Spill into pond --200 gallons	3.8E-07	3.2E-04	1.6E-06	6.9E-10	2.0E-10

N.B. Risks are upper 95 percent confidence limits.

Table 4-15--Lifetime risk of death or cancer resulting from everyday activities.

Activity[a]	Need to accumulate a one-in-one million[a] risk of death	Average annual risk[b] per capita
Motor vehicle accident	1.5 days	2×10^{-4}[c]
Falls	6 days	6×10^{-5}
Drowning	10 days	4×10^{-5}
Fires	13 days	3×10^{-5}
Firearms	36 days	1×10^{-5}
Electrocution	2 months	5×10^{-6}
Tornados	20 months	6×10^{-7}
Floods	20 months	6×10^{-7}
Lightning	2 years	5×10^{-7}
Animal bite or sting	4 years	2×10^{-7}
Occupational risks		
General		
Manufacturing	4.5 days	8×10^{-5}
Trade	7 days	5×10^{-5}
Service and government	3.5 days	1×10^{-4}
Transport and public utilities	1 day	4×10^{-4}
Agriculture	15 hours	6×10^{-4}
Construction	14 hours	6×10^{-14}
Mining and quarrying	9 hours	1×10^{-3}
Specific		
Coal mining (accidents)	14 hours	6×10^{-4}
Police duty	1.5 days	2×10^{-4}
Railroad employment	1.5 days	2×10^{-4}
Fire fighting	11 days	8×10^{-4}
Everyday risks		
Eating and drinking	40 diet sodas (saccharin), 6 pounds of peanut butter (aflatoxin), 180 pints of milk (aflatoxin), 200 gallons of drinking water from Miami or New Orleans, 90 pounds of broiled steak (cancer risk only)	
Smoking	2 cigarettes	

[a] Based on living in the United States.
[b] Note: to calculate the risk over a lifetime, multiply this column by 70. (From Crouch and Wilson, (1982).)
[c] Cancer risks shown in this table were calculated based on a variety of assumptions that tend to overestimate risk as explained in Section 5.
[d] All of these numbers shown exponentially are to be interpreted as follows:

- 10^{-7} means 1 out of 10 million individuals exposed to a given herbicide by means of a given exposure scenario.
- 10^{-8} means 1 out of 100 million individuals,
- 10^{-9} means 1 out of 1 billion individuals

[e] Not used in aerial applications.

Table 4-16--Petroleum distillate: Diesel oil + kerosene margins of safety.

	Systemic		Reproductive	
	Typical exposures	Worst case exposures	Typical exposures	Worst case exposures
		Public		
Dermal				
Veg. contact	6,300.0	3,200.0	10,000.0	10,000.0
Dermal & inhalation				
Drift	470.0	76.0	10,000.0	7,706.8
Dietary				
Water	6,800.0	1,100.0	10,000.0	10,000.0
Fish	2,100.0	330.0	10,000.0	10,000.0
Meat	10,000.0	1,800.0	10,000.0	10,000.0
Peas or beans	870.0	170.0	10,000.0	10,000.0
Berries	1,700.0	320.0	10,000.0	10,000.0
Cumulative				
Fisherman	1,300.0	240.0	10,000.0	10,000.0
Hunter	1,000.0	200.0	10,000.0	10,000.0
		Workers		
Pilot	2,500.0	420.0	10,000.0	10,000.0
Mixer/loader	1,100.0	140.0	10,000.0	10,000.0
Observer	470.0	76.0	10,000.0	7706.8
Card checker	180.0	59.0	10,000.0	5953.5
E.E. Team	88.0	22.0	8971.2	2232.6
		Accidents		
Spill onto worker		-99.0		1.0
Broken hose		-3.2		32.0
Accidental spray		45.0		4604.2
Spill into water				
200 gallons into pond		1.6		163.0

Note: Margins of safety greater than 10,000 are listed as 10,000. Margins of safety were based on a systemic NOEL of 7.38 and a reproductive NOEL of 751.

Table 4-17--Acephate wildlife risk.

Representative species	Realistic dose (mg/kg)	Extreme dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference species
Flicker	2.1	10.8	21.2	106	Dark-eyed junco
Dove	1.7	8.6	21.2	106	Dark-eyed junco
Jay	2.2	11.1	21.2	106	Dark-eyed junco
Kingfisher	0.9	4.7	21.2	106	Dark-eyed junco
Screech Owl	2.9	14.7	21.2	106	Dark-eyed junco
Mouse	6.3	31.4	30	150	Mouse
Rabbit	0.8	5.5	106	530	Rabbit
Deer	0.09	1.1	173	866	Rat
Fox	0.5	2.5	173	866	Rat
Toad	2.9	14.3	1,287	6,433	Green frog
Snake	3.6	17.8	1,287	6,433	Green frog
Cow	0.07	1.3	173	866	Rat
Chicken	0.28	1.5	114	568	Chicken
Dog	0.11	0.5	173	866	Rat

Table 4-18--Carbaryl wildlife risk.

Representative species	Realistic dose (mg/kg)	Extreme dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference species
Flicker	1.1	11	156	780	Grouse
Dove	0.9	8.8	156	780	Grouse
Jay	1.2	11	156	780	Grouse
Kingfisher	0.5	4.7	156	780	Grouse
Screech owl	1.5	15	156	780	Grouse
Mouse	3.3	32	55	275	Mouse
Rabbit	0.4	5.7	142	710	Rabbit
Deer	0.05	1.1	40	200	Mule deer
Fox	0.3	2.6	30	150	Cat
Toad	1.5	14.6	156	780	Grouse
Snake	1.9	18.2	156	780	Grouse
Cow	0.04	1.4	40	200	Mule deer
Chicken	0.15	1.5	156	780	Grouse
Dog	0.06	0.5	30	150	Cat

Table 4-19--Malathion wildlife risk.

Representative species	Realistic dose (mg/kg)	Extreme dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference species
Flicker	3.8	21.1	30	150	Chicken
Dove	3	16.8	30	150	Chicken
Jay	3.9	21.8	30	150	Chicken
Kingfisher	1.6	8.9	30	150	Chicken
Screech owl	5.2	28.9	30	150	Chicken
Mouse	11	62.2	155	775	Mouse
Rabbit	1.4	10.8	10.6	53	Rabbit
Deer	0.15	2.1	16	80	Dairy calves
Fox	0.86	4.8	74	370	Rat
Toad	3.6	20.4	30	150	Chicken
Snake	4.5	25.2	30	150	Chicken
Cow	0.12	2.6	16	80	Dairy calves
Chicken	0.47	2.8	30	150	Chicken
Dog	0.17	0.9	74	370	Rat

Table 4-20--Diesel oil wildlife risk.

Representative species	Realistic dose (mg/kg)	Extreme dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference species
Flicker	4	40.4	3,280	16,400	Mallard
Dove	3.3	32.8	3,280	16,400	Mallard
Jay	4.2	41.7	3,280	16,400	Mallard
Kingfisher	1.9	18.9	3,280	16,400	Mallard
Screech owl	5.5	54.8	3,280	16,400	Mallard
Mouse	11.3	113	1,476	7,380	Rat
Rabbit	1.6	21.3	1,476	7,380	Rat
Deer	0.2	4.3	1,476	7,380	Rat
Fox	1	10.3	1,476	7,380	Rat
Toad	11.8	118	3,280	16,400	Mallard
Snake	15	150	3,280	16,400	Mallard
Cow	0.15	4.9	1,476	7,380	Rat
Chicken	0.63	6.7	3,280	16,400	Mallard
Dog	0.3	2.9	1,476	7,380	Rat

Table 4-21--Kerosene wildlife risk.

Representative species	Realistic dose (mg/kg)	Extreme dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference species
Flicker	1.1	11.6	3,280	16,400	Mallard
Dove	0.9	9.5	3,280	16,400	Mallard
Jay	1.2	12	3,280	16,400	Mallard
Kingfisher	0.5	5.5	3,280	16,400	Mallard
Screech owl	1.6	15.8	3,280	16,400	Mallard
Mouse	3.2	32.5	5,600	28,000	Rat
Rabbit	0.5	6.1	5,600	28,000	Rat
Deer	0.06	1.2	5,600	28,000	Rat
Fox	0.3	3	5,600	28,000	Rat
Toad	3.3	34	3,280	16,400	Mallard
Snake	4.2	43.2	3,280	16,400	Mallard
Cow	0.04	1.4	5,600	28,000	Rat
Chicken	0.18	1.9	3,280	16,400	Mallard
Dog	0.08	0.8	5,600	28,000	Rat

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APPENDIX A

ENVIRONMENTAL FATE

Malathion

Physical and Chemical Properties

Malathion is an organophosphate insecticide that exists as a colorless to light amber liquid at standard conditions (25 ^{o}C, 1 atmosphere pressure.) The preferred chemical name of malathion is 0,0 dimethyl phosphorodithioate of diethyl mercaptosuccinate. (Figure A-1 shows its chemical structure.) Its physical and chemical properties are listed in Table A-1 (Dobroski and Lambert, 1984).

Fate in Soil

EPA (1986a)cites a soil half-life for malathion of 1 day. In alkaline soils with low organic content and low microbial populations, basic hydrolysis may be the primary reaction in the degradation of malathion. Reaction half-lives on the order of 7.5 to 11 days were found in low organic content of soils in the rangeland (Buckman and Brady, 1969).

Degradation of malathion in higher organic content soils occurs through biologically mediated catalysis by exoenzymes and nonbiologicalhydrolysis. The breakdown of malathion by exoenzymes occurs from enzyme activity in soil humus and the metabolic activity of microbes. Degradation by enzymes in soil humus is the most rapid process; thus, malathion is rapidly consumed in moist soils with significant organic content (Gibson and Burns, 1977). A soil half-life of 0.5 days has been reported (Curley and Donohue, 1986). Degradation by direct metabolic activity of soil microbes is important only when the enzyme is not present in soil organic matter (Getzin and Rosenfield, 1971). Microbes that metabolize malathion include species of the bacteria Anthrobacter and Tricoderma and the fungi Rhizobium (Matsumura and Baush, 1966; Walker and Stojanovic, 1973).

Malaxon is a common degradation product of malathion in the soil. It is of concern because its toxicity level is similar to that of malathion. Degradaton of malaoxon is primarily by basic hydrolysis (Pascal and Neville, 1976), and hal-lives of 3.9 to 5 days wre found for soils of pH 7.2 topH 8.2. This indicates that basic hydrolysis will lead to rapid degradation of malaoxon under conditions found in soils of the western States.

Transport of malathion from the soil environment to the atmosphere should be negligible because malathion is a chemical of low volatility (1.25×10^{-4} mm Hg at 20 ^{o}C). Leaching of malathion from the soil zone also should be minimal because of the low moisture content of the soils during the application period and the low permeability and relatively high sorpton capacity of smectitic soils (Borchardt, 1977). An adsorption coefficient (Kd) of 892 mL/g has been reported (Curley and Donohue, 1986). EPA (1986a) cites an adsorption coefficient of 20 mL/g.

Fate in Air

Photolysis of malathion and related compounds is too slow to be considered important to the degradation of malathion (Toia et al., 1980). However, the low volatility of malathion discounts both the likelihood of its presence in air as a vapor and its persistence of the atmosphere. Significant transport of malathion should occur only by drift during application.

Fate in the Aquatic Environment

Degradation of malathion in aquatic environments occurs through basic hydrolysis and microbial activity. Wolfe et al. (1977) found a 36-hour half-life for malathion from basic hydrolysis (pH 8, 27 ^{o}C). Degradation products and reaction intermediates include DPTA, diethyl fumarate, monocarboxylic and dicarboxylic acids of malathion, and thiosuccinic acid. Malathion monoacids are also products of hydrolysis and have a half-life of 26 days for inorganic degradation. Biological degradation has been reported to eliminate malathion from river water in 28 days with 75 percent removed in 1 week (Eichelberger and Lichtenberg, 1971). Malathion monoacids have been detected as the primary degradaton products from biological reactions. The monoacids persist after malathion has been eliminated (Bourquin, 1977). The degradation products of biological reactions are eliminated only by further degradation reactions (Wolfe et al., 1977). The degradation of malathion may be accelerated by photolysis under ultraviolet radiation. Natural river water with a large amount of organic matter resulted in a half-life for malathion of 15 to 16 hours under sunlight photolysis (Wolfe et al., 1977).

Malathion may be removed from aquatic environments by adsorption to suspended particulates (half-life of 3 days for estuarine sediments (Walker, 1976). Because of its physical properties, malathion is not removed from aquatic environments by volatilication or precipitation as a solid.

Fate in Plants

Degradation of malathion on plant surfaces has been reported with half-lives of 15 to 21 hours (Saini and Dobough, 1970) to 5 days (Nigg et al., 1981). Half-lives of ULV applications of malathion at 29.4 ^{o}C and 40.5 ^{o}C were 21 and 15 hours, respectively. He half-life of malathion residues on citrus foliage was found to be approximately 5.2 days. Residues of emulsifiable concentrate and half-lives of approximately half the ULV residues. Degradation or disappearance of malathion from plant surfaces showed varying rates. The interval for complete dissipation of malathion by bioassay) was 5 days on bean plants and 6 days on clover plants. For peaches, the safe interval between malathion treatment and consumption was 1 to 2 days (Dobroski and Lambert, 1984). Trace levels of malathion on plants after 1 week have also been found in other studies (Kashyap and Hameed, 1982).

Malathion has been found to damage a variety of fruit trees and vegetable plants (Thomson, 1979). Affected plants include string beans, apples Bosc pears, cherries, European grapes, and cucurbits. Some ornamental plants were also affected by malathion. Phytotoxicity of malathion to forested areas was not observed after application at 0.72 lb a.i./acre (Giles, 1970).

Bioaccumulation

The bioaccumulation potential for malathion is low. Its low octanol-water partition coefficient (780) and high solubility (145 mg/L at 18 ^{o}C) reflect its low potential for accumulation in lipids (Dobroski and Lambert, 1984). In acidic waters, where malathion is more stable, carp did not bioaccumulate significantly above the level in the water (Bender, 1969). Retention after exposure revealed a half-life of 1 hours in tissue, reflecting relatively rapid elimination of malathion from tissues after cessation of exposure (Kenaga and Goring, 1980).

Carbaryl

Chemical and Physical Properties

Carbaryl is a carbamate pesticide that exists as a white, crystalline powder in pure form and is tan, lavender, or pink in its technical formulation. The chemical name of carbaryl is 1-napthyl (N-methyl-carbamate). (Figure A-2 shows the structure of carbaryl.) Its physical and chemical properties have been summarized in Dobroski (1985). (See Table A-2.)

Fate in Soil

EPA (1986a) reports a soil half-life of 14 days for carbaryl. Degradation of carbaryl in the soil zone results primarily from the metabolic activity of microorganisms (Heywood, 1975). A half-life in soil of 8 days has been reported by Johnson and Stansbury (1965). Only 6 percent of applied carbaryl could be recovered from treated soil 28 days after application.

In addition, less than 3 percent remained as water-soluble metabolites. Degradation of carbaryl by soil microorganisms produces several toxic reaction intermediates, including 1-napthol and hydroxy-methylcarbamates. Heywood (1975) also found that 68 percent of hydroxylated metabolites were broken down in soil after 9 weeks. Soils placed in storage were found to degrade a variety of carbamate insecticides at a low rate. Carbaryl has been found to be degraded by the soil fungus *Aspergillus terreus* (Liu and Bollag, 1971). Carbaryl degraded with a half-life of 6 days in *A. terreus* cultures, and 1-napthol also metabolized into unidentified degradation products. Soil mite populations are unaffected by carbaryl (Moulding, 1972). Catalysis of carbaryl degradation by soil minerals is not well understood, but it is clear that the degradation of carbaryl in soils can be attributed more to biological activity than to soil mineral composition (Heywood, 1975).

Field applications of carbaryl were conducted to determine the potential for ground-water contamination (LaFleur, 1976. Soil and ground-water samples were taken at monthly intervals. No carbaryl was found in the upper 20 cm of soil after the fourth month (initial application of 50 micromoles per kilogram (umol/kg) soil. Carbaryl desorption values (k_b) of 1.6 to 0.31 were calculated from field data, and sorption was correlated to organic content of the soil. EPA (1986a) reports an adsorption coefficient of 2.2 mL/g. Concentrations of carbaryl in ground water peaked at 0.3 umol/L (60 ppb) 2 months after application and dropped to 0.1 umol/L after 4 months. These values represent a maximum for potential migration to ground water because of field conditions (water table depth of 1.1 m and precipitation of 11.4 cm/month). At expected water table depths and precipitation rates in most

rangeland application areas, migration of carbaryl to ground water is highly unlikely. Little transport of carbaryl by soil water is expected because of its low solubility (40 ppm) and rapid degradation in soils.

Because of its low volatility (0.005 mm Hg) Dolinger and Fitch, 1979), transfer of carbaryl from soils to the atmosphere is too slow to be significant in removing carbaryl from soil.

Fate in Air

Carbaryl is not expected to be present in air as a vapor because of its low volatility (0.005 mm Hg). Studies of ambient air concentrations of pesticides have not detected carbaryl (Kutz et al., 1976).

Fate in the Aquatic Environment

Carbaryl degrades rapidly in water in 1 to 5 days. Carbaryl applied over open water, such as small brooks or ponds, at an initial deposit of 1 ppm or less in water depth of about 4 inches may be expected to degrade completely or disappear in 1 or 2 days (Romine and Bussian, 1971; California Department of Fish and Game, 1963; Lichenstein et al., 1966). Results were similar for water treated with Sevin 4-Oil during a gypsy moth suppression project (Willcox, 1972).

The biodegradation rate constant for carbaryl in water is 2.4×10^{-10} mL of substrate/bacterial cell/day (Lyman et al., 1982). The greater the number of bacterial cells in the water, the faster carbaryl will biodegrade. The major metabolite of microbial degradation of carbaryl is 1-naphthol. In a detailed 3-year study of carbaryl in aquatic environments (Felley, 1970), no residues of carbaryl or its major metabolite, 1-naphthol, ever exceeded 0.1 ppm in areas where the pesticide was applied at 1 lb per acre. The ultimate degradation product is carbon dioxide, but investigators in one study suspected that 1-naphthol may be converted to an unidentified, but fairly stable, metabolite that is approximately two-thirds as toxic as 1-naphthol to organisms such as bay mussels (Lamberton and Claeys, 1070).

Carbaryl may be rapidly degraded by hydrolysis at neutral to alkaline pH values (Wolfe et al., 1978; Aly and El-Dib, 1971). These kinetic studies determined half-lives of 1.3 to 1.5 days at a pH of 8 (similar pH values are expected in the rangeland areas of application). Wolfe et al. (1978) found a half-life for photolysis of carbaryl of 6.6 days. Carbaryl was found to be less persistent in natural water at higher pH values (Szeto et al., 1979). This study found biological degradation was significant in the removal of carbaryl; however, these waters existed under conditions that retarded hydrolysis (pH less than 7.5, 9 ^{o}C). Only 5 percent of applied carbaryl was recovered from river water after 1 week (Eichelberger and Lichtenberg, 1971).

Under conditions expected in the area sprayed to control spruce budworm, hydrolysis and photolysis should be primary pathways for the degradation of carbaryl, and rapid elimination is indicated in studies of laboratory and natural samples.

Fate in Plants

The low vapor pressure of carbaryl makes it unlikely that it will volatilize from plant surfaces. The susceptibility of carbaryl to photolysis and its low solubility minimize the possibility of washoff from plants.

Various field studies have been conducted to determine the persistence of carbaryl residues on plants. REsidues of Sevin 4-Oil, applied at 0.75 lb a.i./acre in northeastern forests, were found on foliage 60 days after treatment (Ghassemi et al., 1981). A field study of carbaryl residues on foliage, when Sevin 4-Oil was applied at 1 lb a.i./acre, showed the half-life on grass as 8 days, on geraniums as 3 days, on aspens as 8 days, and on Douglas-fir as 4.5 days (Pieper, 1979). This study also reported grass to have the highest percent residue recovered (89.5 percent). In a field study in India, the half-life calculated for cabbage was 3 days and 3.2 days for eggplants (Mann and Chopra, 1969). The calculated half-life of carbaryl, when applied to apple leaves at 0.5 and 1 lb a.i./100 gal, was 13.33 days with a 90-percent reduction in the average surface residue 31 days after treatment (Sell and Maitlen, 1980). When applied to lemon and orange trees at 11.5 lb a.i./acre, residues were reduced by 83 percent and 94 percent, respectively, by 60 days after treatment; and calculated half-lives were 14 days on orange leaves and 22 days on lemon leaves (Iwata et al., 1979). Dissipation rates 8 days after treatment were 81 to 88 percent for spinach and 82 to 85 percent for chicory. Tilden and van Middelem (1970) reported that the rate of dissipation of carbaryl on plants appears to be independent of the initial concentration. The following allowable and actual carbaryl residues were reported for citrus and soybeans; (1) 10 ppm residues were allowable for citrus, and 2 to 8 ppm were found 5 days after treatment (1 lb/100 gal); and (2) 5 ppm residue are allowable for soybeans with 0.96 ppm found 38 days after application (1 to 2 lb a.i./acre (Clement Associates, 1978). In summary, although dissipation rates of surface residues do not very according to initial concentrations, the proposed application rate of 0.5 lb/a.i./acre (8 oz a.i./acre) of carbaryl for the spruce budworm control program is lower than any of those reported in the above studies. Therefore, original residues (in ppm) should be lower than those reported.

Small amounts of carbaryl may be absorbed by roots and foliage and distributed into plants (EPA, 1984). Higher plants have been found to produce some metabolites that remain n the plant tissue and cannot be removed by the usual extraction procedures (Casida and Lykken, 1969; Dorough and Wiggins, 1969). Injection of carbaryl into bean plants led to production of water-soluble compounds that were stable within the plant (Kuhr and Casida, 1967). Studies on bean and cotton plants showed carbaryl to have a 3- to 7-day half-life (Dorough et al, 1963). The plant systems responsible for these changes may be enzymatic and may catalyze hydrolysis of the carbamate (Casida, 1963).

Although a portion of the metabolites produced in higher plants is water soluble and may enter the body of animals when the plants are eaten, these soluble metabolites are quickly eliminated (for example, more than 90 percent is eliminated after 96 hours in rats) by way of the urine and feces (Casida and Lykken, 1969; Dorough and Wiggins, 1969). Of six known higher plant metabolites administered to rats, five were less toxic than carbaryl. The remaining metabolite was more toxic than carbaryl, but it was noted that the metabolite is produced only by a minor metabolic pathway in plants (Wiggins et al, 1970).

Carbaryl is nontoxic to most plant when applied at label rates (Amer, 1965). Carbaryl has been found to injure boston ivy, Virginia creeper, and maidenhair fern (Union Carbide, 1982), as well as pears, watermelons, and some types of apples (Thomson, 1979). Minor stunting of conifer seedlings also has been observed (Sutherland et al., 1977), and retarded germination of grasses may result from excess dosages of carbaryl (Thomson, 1979). Carbaryl may induce abnormal cell mitosis and meiosis in root tips, but recovery occurs within 48 hours (Amer and Farrah, 1968; Amer, 1965). Seed viability may be increased because of the fungicidal action of carbaryl (Eid et al., 1971).

Biological Uptake

Carbaryl is not subject to significant bioaccumulation in aquatic ecosystems because of its low solubility and low octanol-water partition coefficient (K_{ow} = 230) (Dobroski, 1985). Uptake of carbaryl in fish has been detected, with 95 percent excreted within 8 hours (Tompkins, 1966).

<u>Acephate</u>

Chemical and Physical Properties

Acephate is an organophosphate insecticide that is an acetylation product of methamidophos. The chemical name is 0,S-dimethylacetylphosphoramidothioate. (Figure A-3 shows the structure of acephate.) Its physical and chemical properties are listed in Table A-3 (Lambert, 1985).

Fate in Soil

A half-life of 7 days has been reported for acephate by EPA (1986a). Microorganisms degrade acephate in the soil. Bacteria have been identified that can use acephate as their sole source of phosphorous (Rosenberg and Alexander, 1979). Some soil fungi also can degrade acephate (Liu and Bollag, 1971). No adverse effects on soil organisms have been attributed to acephate (Focht and Joseph, 1974; Dutcher and Sheppard, 1981).

Nonbiological degradation is not important in the removal of acephate from soil. The biological breakdown rate of acephate depends on the soil type and its moisture content. A half-life of 0.5 to 6 days (at 1 ppm of acephate) has been reported (USDA, 1976). During degradation of acephate in soil under a variety of conditions, less than 10 percent of acephate was converted to methamidophos; most was converted directly to innocuous salts.

A soil adsorption coefficient (Kd) of 4.24 has been reported (Curley and Donohue, 1968). EPA (1968a) reported a Kd of 0.1. Because of its high solubility (65 g/100 ml) and low adsorption to soil materials, acephate is susceptible to leaching in the soil zone under some conditions. Acephate was completely leached from soil columns diluted with 4 to 10 inches of water regardless of soil texture (Tucker, 1972c). Studies of aged soils revealed that the remaining acephate (0.02 to 0.05 pom) could be leached from soil columns; but most acephate had degraded to immobile metabolites, and methamidophos was not detected (Warnock, 1972). Acephate is quite mobile when present. Most acephate breaks down into immobile degradation products before significant transport, even under high rainfall conditions (Chevron, 1973).

Fate in Air

Acephate has low volatility (equilibrium concentration of 2 ppb). Ambient air tests and photolysis experiments, summarized in lambert (1985), indicate that it is not transferred to the atmosphere from the ground or plant surfaces. Acephate is also relatively resistant to photolysis and does not degrade at a significant rate upon exposure to sunlight.

Fate in the Aquatic Environment

Acephate breaks down relatively slowly in water. The rate of hydrolysis is affected by temperature, pH, and alkalinity. The half-life in water at pH 7 and approximately 70 ^{o}F is about 47 days under laboratory conditions (Etter and Tissier, (1973).

Acephate is degraded in water by basic hydrolysis. At a pH of 8.2 and a temperature of 20 ^{o}C (68 ^{o}F), 78 percent of acephate was recovered from solution after 20 days. At 30 ^{o}C (86 ^{o}F), only 18 percent was recovered after 20 days (Szeto et al., 1975). Under expected spruce budworm control application conditions, basic hydrolysis may be significant in the removal of any acephate that may accidentally reach aquatic environments. Szeto et al. (1979) also fund that more than 75 percent of applied acephate remained in natural water samples after 45 days; however, the samples were stored at 9 ^{o}C (48 oF), so the experiment shows a minimum degradation rate. Also, the presence of bottom sediments in natural waters more than doubled the degradation rates. Field application to surface waters resulted in higher degradation rates. In natural bodies of water, degradation is accelerated by breakdown in aquatic vegetation and microorganisms in sediment. A half-life of 3 to 15 days was reported for ponds in floride and Iowa treated with 0.1 ppm of acephate (Cheveron, 1973). Half-lives ranged between 1 and 3 days in the bottom sediments.

Controlled release of acephate into a flowing creek in British Columbia at 1 ppm was monitored to determine the fate of acephate in natural waters (Hussain and Oloffs, 1980). Acephate concentrations of 1.1 ppm were detected 150 meters downstream during the release of acephate, and levels decreased to 40 ppb within 1 hour of the end of acephate release. At a distance of 2,000 meters downstream, acephate levels peaked at 160 ppb after 8 hours and dropped to 2.7 ppb after 96 hours. No methamidophos was detected in the waters. Acephate and methamidophos dropped to trace levels in sediments after 2 days.

The neutral or alkaline waters typical of the West and the microorganisms present in sediments and vegetation of acquatic environments would be expected to cause relatively rapid degradation rates of acephate.

Fate in Plants

Residue levels based on chemical analyses were reported as part of a tussock moth control program in Canada (Szeto et al., 1979). For an aerial application rate of 1.12 kg/ha (1.0 lb a.i./acre), decay half-lives in the range of 3 to 6 days were found with no detectable concentrations of acephate or its metabolite methamidophos after 60 days. The vertical distribution of acephate residues was highest in the tree crown area and lowest near the ground. The application

rate of this study is considerably higher than the 0.094 lb a.i./acre (1.5 oz a.i./acre) acephate proposed for the spruce budworm control program.

The degradation of acephate on plants is thought to follow a common pattern. The fraction of insecticide not absorbed by plant tissue immediately upon application is subject to washoff, other degradation mechanisms, transport from the plant, and chemical/microbiological breakdown (Robertson and Boeller, 1979). Dislodgeable residues have been found to have a half-life of 24 hours on plant surface (Bull, 1978). From the fraction of insecticide absorbed by the plant, 5 to 10 percent is metabolically transformed to methamidophos. Both the remaining acephate and methamidophos are metabolically degraded over time to innocuous salts (USDA, 1976).

Acephate has low or no phytotoxicity for ornamental and tropical plants at proposed application rates. Application is not recommended for American elm, flowering crabapple, sugar maple, cottonwood, or huckleberry (Thomson, 1979). Acephate is toxic to pine seeds and inhibits germination of white spruce and pine seeds but increases germination of yellow birch.

Bioaccumulation

Acephate has a very low potential for bioaccumulation. The octanol/water partition coefficient is 0.04 (Larson, 1975

A study in which acephate was injected into a stream showed that fish and insect larvae demonstrated both uptake of acephate and conversion of acephate to methamidophos. Fish uptake of acephate was approximately 1 to 4 percent of the total acephate in the stream. Approximately 4 to 8 percent of that was converted tomethamidophos. By 1 day after injection of acephate, both acephate and methamidophos were cleared from fish tissue. Similarly, insect larvae demonstrated acephate uptake (17 percent of water concentration) and conversion to methamidophos (63 percent of tissue acephate concentration) Tissue levels of acephate and methamidophos were below detection levels 3 hours after termination of acephate release into the stream. The conclusion of the study was that acephate applied in the low ppm level to a natural stream would not be persistent in the water, sediments, or organisms beyond 1 to 4 days, that the levels of acehate and methamidophos encountered would not be bioaccumulated (although they would show uptake in fish and insect larvae), and that acephate would not be acutely toxic to stream organisms (Hussain and Oloffs, 1980; Geen et al., 1981).

Studies using food chain organisms in model ecosystems containing algae, daphnids, emergent plants, insects, and mosquito fish concluded that residues of acephate and its metabolites were not persistent and did not biomagnify along the food chain or accumulate in any ecosystem component. Acephate residues were found only in the model ecosystem water. Metabolic fragments were found incorporated into various tissues, and no acephate residues were detected in fish tissues (Booth, 1975; USDA, 1976).

Bluegill were continuously exposed to 0.01 and 1.0 mg/L acephate for 35 days. A concentration 10 times as high of acephate residues in their tissue occurred as long as exposure occurred. This uptake followed a dose-response relationship in which tissue levels were proportional to environmental levels of acephate in their water. Upon transfer to uncontaminated water, fish

exposed to both levels of acephate eliminated more than 50 percent in their edible portions within 3 days. It was concluded that his level of bioaccumulation was minimal and posed no serious threat to the food chain (USDA, 1976).

A study of Hall and Kole (1980)showed that with normal application rates of acephate bioaccumulation by some amphibians may occur that could threaten other nontarget organisms. Another study using tadpoles indicated that acephate did not bioaccumulate to levels that threatened mallard ducklings (Lyons et al., 1976). Tadpoles accumulated acephate in their body tissues but only to concentrations approximately equal to ambient levels. The authors estimated that, at maximum body concentrations anticipated from normal application rates, an adult mallard would have to consume 4,7000,000 tadpoles to reach lethal levels. This does not rule out possible sublethal effects, such as changes in cholinesterase activity, but it does indicate a wide margin of safety to certain predators of tadpoles.

<u>Methamiphodos</u>

Physical and Chemical Properties

Methamidophos is a transformation product and metabolite of acephate. It is also a manufactured organophosphate insecticide by the trade name of Monitor. The chemical name is 0,S-dimethyl phosphoramidothioate. Its chemical structure is shown in Figure A-4. Table A-4 lists its chemical and physical properties.

Fate in Soil

Less than 10 percent of acephate residues are present in soil as methamidophos at any one time (Tucker, 1972b). Methamidophos degrades rapidly in soil with a half-life of 6.1 days in sandy soils and 1.9 days in silt (initial concentration 1 ppm) (Leary and Tutass, 1968).

At a higher initial concentration (20 ppm), degradation was still fairly rapid in a sandy loam soil with a half-life of 10 to 12 days at 24 ^{o}C (Tucker, 1972a).

Methamidophos is expected to be moderately mobile to very mobile in most types of soils (Dynamac, 1981).

Fate in Air

No information is available on the transformation of acephate to methamidophos in air. See the discussion on acephate for information on fate.

Fate in the Aquatic Environment

Some fraction of acephate may be transformed to methamidophos in aquatic environments; however, no information is available on the rate or extent of this conversion (Lambert, 1985). Methamidophos, like acephate, is degraded by basic hydrolysis and has a similar half-life--44 days and 46.4 days, respectively (pH 7 and 21 ^{o}C) (USDA, 1976).

Fate in Plants

Methamidophos residues on tomato plants treated with acephate reached a maximum concentration of acephate at 2 days after spraying (Leidy et al., 1978).

Five to ten percent of the acephate absorbed by a plant is metabolized to methamidophos (USDA, 1976). Similar values were reported by EPA (1985) of up to 10 percent.

The initial half-life of methamidophos residues on tomato plants is 7 to 10 days (FDA, 1980).

Bioaccumulation

Field studies with 0.5 lb a.i./acre acephate have shown methamidophos residues in grasshoppers of 2.6 to 4.6 ppm (wet weight) at 4 hours after spraying and 0.5 to 0.7 ppm at 53 hours after spraying. These residues were approximately 29 percent and 24 percent, respectively, of the total acephate-methamidophos residues (EPA, 1986c).

Uptake of acephate by fish is approximately 1 to 4 percent of stream concentrations, with approximately 4 to 8 percent being converted to methamidophos after uptake. Aquatic insect larvae showed higher uptake rates (17 percent) and higher conversion rates (63 percent) (Lambert, 1985).

Studies with mammals have shown transformation of acephate tomethamidophosin the gut at levels of 0.6 to 10 percent (EPA, 1985. Methamidophos is rapidly eliminated in the breath and urine. Goats given 3.75 mg methamidophos daily produced milk with a concentration of 0.003 ppm of parent methamidophos.

Bacillus thuringiensis

Degradatin of *B.t.* spores and crystals (i.e., reduction in the number of viable spores) is attributable to solar radiation, temperature, and vapor pressure deficits (Leonge et al., 1980, as cited in Sassaman, 1987). Vegetative cells, on the other hand, are subject to the bactericidal effects of various juices and extracts of many plants (Gorsberg et al., (1976). The persistence of vegetative cells of *B.t.*, as well as of activity of the various toxic entities of *B.t.*, is strongly dependent on the specific nature of the formulation used and on various environmental parameters, such as sunlight, humidity, and soil conditions. Viable spores last from a few days to weeks depending upon environmental conditions (Sassaman 1987).

Fate in Soil

Persistence in *B.t.* in soils was reviewed by Forsberg et al. (1976). *B.t.* formulations appear to be moderately persistent.

Ignoffo and Graham (1967) reported a 90-percent reduction in spore count after 4 months for Bakthan L-69 (75 x 10^9 spores/g) applied to soil that was exposed to the atmosphere and to 7.28 inches of rainfall (Forsberg et al., 1976, as cited in Sassaman, 19870. Saleh et al. (1970) treated various soils with Thuricide T (liquid emulsion of 30 x 10^9 spores/g) and with Biotrol BTB wettable powder(specific activity not provided). They reported recovery of 7,800 to 170,000 spores/g of soil from silty clay and from two silt loams up to

40 days after application. In laboratory soil studies, these authors reported that B.t. spores germinated and exhibited population growth in organically amended soils, but in low pH (5.2) soil that has not been organically amended, the spores germinated while the vegetative cells died.

Fate in Air

Little data are available on the behavior and fate of B.t. in the atmosphere. Smirnoff et al. (1973, as cited in Sassaman, 1987) reported persistence of B.t. in the air for as long as 17 days after aerial application of B.t. var. thuringiensis (Thuricide HPC) to a mixed coniferous forest (specific details of amounts and concentration were not provided).

Fate in Water

There are no reports in the literature abut the behavior and fate of B.t. formulation and of specific toxins such as the delta-endotoxin in aquatic systems. Buckner et al. (1974, as cited in Sassaman, 1987) reported that river water, sampled 30 minutes after a 2,500 acre watershed had been treated with 4 BIU/ha of Thuricide 16 B, contained 1,730 spores/ml. Analysis of the water 30 days after application revealed no presence of B.t. spores. Buckner et al. (1974, as cited in Sassaman, 1987) reported B.t. concentrations of 22,800 spores/ml following a spray over water. After refrigeration in darkness for 2 months, 7,800 spores/ml were cultured from the same water.

Fate in Plants

The primary concern addressed by most of the available literature on B.t. fate in plants is the potential loss of insecticidal activity of the formulations as a result of bactericidal action of the plant fluids (Sassaman, 1987). Forsberg et al. (1976, as cited in Sassaman, 1987) have reviewed the literature on the effects of plant-derived bactericidal chemicals on B.t. Smirnoff (1967, cited Sassaman, 1987) tested the effects of volatile substances from the crushed foliage of 34 species of plants. He reported that the effects of viability of the bacteria varied among different varieties of B.t. and between cells and spores of each variety, with the vegetative cells generally more sensitive to the plant bactericidal chemicals than were the spores.

Pinnock et al. (1971, 1974, and 1975, as cited in Sassaman, 1987) reported a series of studies on the fate of B.t. formulations after application to various plants. Following application of Thuricide 90 TS to oak trees in an unspecified concentration, the viable-spore half-life was determined to be 3.9 days in a cool moist climate and 7.7 days in a hot, dry climate. Biotol BTB 183 dust and wettable powder, applied to oak trees in a hot dry climate had viable spore half-lives of 22.7 days and less than 1 day, respectively. Following application of Amdal (Dipel WP was formerly marketed as Amdal B.t. wettable powder), Biotrol, and two formulations of Thuricide, a two-phase loss in viability was reported, with half-lives of 0.58 to 1.85 days for days 0 to 3 and of 1.20 and 2.66 days for days 3 to 7. When Dipel was applied to the point of runoff to 4 species of trees (California live oak, red bud, eucalyptus, and walnut), the viable spore half-lives ranged from 0.38 to 0.90 days. Deposition of the spores was not uniform on all tree species, and it was speculated that specific characteristics of tree morphology may have affected the patterns of

initial spore deposition and subsequent decrease in viability of the B.t. spores (Sassaman 1987).

Angus et al. (1970, Sassaman, 1987) monitored the numbers of viable spores of B.t. following aerial application of Thuricide 90 TS to a mixed balsam fir, spruce, and deciduous forest and 0.6 to 1.4 quarts of formulation (specific activity not given/acre. They reported that only 15 percent were viable 72 hours after application.

Hamlen and Henley (1976, as cited in Sassaman, 1987) applied Dipel wettable powder or Thuricide HP, at 1 or 2 lb a.i./100 gal of final spray volume for 4 times at weekly intervals to 10 species of tropical foliage plants. Neither formulation was reported to have any phytotoxic effects. Engelhard (1972, as cited in Sassaman, 1987) reported no effects on the flower quality of chrysanthemums treated with 2 or 4 quarts thuricide 57-428 TC 90 in 100 gallons of water, at 66.2 ^{o}F (19 ^{o}C) or at 85.1 ^{o}F (29.5 ^{o}C), with either 2 or 4 hours drying rate.

Diesel Oil and Kerosene

Physical and Chemical Properties

Diesel oil and kerosene are products of the distillation of raw petroleum (crude oil). Petroleum distillates are fractions of crude oil obtained from refinery distillation processes. These distillates include materials such as aviation fuels, gasoline, lubricating oils, petroleum jelly, wax, and asphalt.

Petroleum Distillation

Petroleum or crude oil consists of hydrocarbons (compounds containing primarily carbon and hydrogen) and to a much lesser degree compounds containing oxygen, nitrogen, sulphur, and other elements. Crude oils are composed of 84 to 87 percent carbon by weight, 11 to 14 percent hydrogen, 0.06 to 2 percent sulphur, 0.1 to 2.0 percent nitrogen, and 0.1 to 2 percent oxygen (Horne, 1978.

Hydrocarbon compounds are divided into two major classes based on structure: the aliphatics and the aromatics (Morrison and Boyd, (1974). (See Table A-5.) Aliphatic hydrocarbons include the alkanes, which have single (saturated) carbon-carbon (C-C) bonds and more reactive alkenes and alkynes, which have double or triple (unsaturated) C-C bonds, respectively. These compounds all have an open-chain structure. The aliphatic group also includes the cyclic aliphatic, or alicyclic, hydrocarbons. These compounds include cyclic or ring compounds formed from the open-chain alkanes, or alkynes.

The aromatic group of hydrocarbons includes benzene and those compounds that have chemical properties similar to benzene. Benzene is a unique cyclic hydrocarbon containing 6 carbon and 6 hydrogen atoms. An important characteristic of the benzene ring is that all the C-C bonds are equal in length and are intermediate between single and double bonds (Morrison and Boyd, 1974). This characteristic is called resonance, and the bonds are represented as a circle in the figures in Table A-5.

The number of carbon atoms and the C-C bonding present in the substance determine a hydrocarbon compound's physical properties, particularly its

melting and boiling point. In general hydrocarbons having the same number of carbon atoms melt and boil at lower temperatures when they have single C-C bonds than when double or triple C-C bonds, those with fewer carbon atoms melt and boil at lower temperatures than those with more carbon atoms. The simplest hydrocarbon, methane (CH_4, is a gas at room temperature, while gasoline (C_6H_{14} to $C_{12}H_{26}$) is a liquid.

Routh et al. (1971) describe the fractional distillation of petroleum obtained from oil wells. The separation of the various fractions (gases, gasoline, kerosene, fuel oil, lubricating oil, etc.) depends on the boiling range of the hydrocarbons that constitute crude oil. Figure A-5 illustrates the separation of crude oil into relatively distinct fractions based on boiling range. Hydrocarbons with fewer carbon atoms, such as gasoline, boil and are recovered by condensation at lower temperatures than kerosene or fuel oil. The boiling ranges of diesel oil and kerosene are shown in Figure A-5 for comparison with other crude oil fractions.

Diesel oil and kerosene have similar properties and characteristics. TAble A-6 lists the chemical and physical properties of diesel oil and kerosene. Diesel oil is composed of molecules ranging from 10 to 25 carbons, with a flash point of approximately 85 ^{o}C (DOE, 1983). Kerosene consists of molecules with 12 to 15 carbon atoms, which are predominantly n-alkanes and monocycloalkanes (Routh et al., 1971; Speight, 1980). Kerosene has a flashpoint of 65.6 to 82.2 ^{o}C (HSDB, 1987). While kerosene's composition differs from that of diesel oil, it is often grouped with diesel oil because its boiling range and its carbon number range fall within those of diesel oil (see Figure A-5).

Crude oil can be separated into various groups of hydrocarbons according to different boiling ranges by the process of straight-run distillation. Products of this distillation process include naphtha, kerosene, light fuel oil, diesel fuel, and gas oil (Bingham et al, 1979). These products can be further refined by using heat in a process known as "cracking." Cracking converts large alkanes and alkenes (Morrison and Boyd, 1974).

Diesel Oil

Diesel oil, usually a straight-run crude-oil distillation product, is a complex mixture of hydrocarbons containing approximately 10 to 25 carbon atoms per molecule (Neumann et al., 1981). Some of the chemical and physical properties of diesel oil are listed in Table A-6. Diesel oil has a boiling range of 175 to 370 ^{o}C. Although diesel oil generally is not miscible with water, certain alcohols, aromatics, and phenols in diesel oil are water soluble (DOE, 1983).

Table A-7 shows the approximate composition of diesel oil. Normal paraffins are straight-chain structures referred to as n-alkanes; they are the simplest hydrocarbons. The lower n-paraffins form a minor component of diesel oil. Some n-paraffins are normal pentane, octane, and dodecane.

Isoparaffins are branch-chain compounds, commonly referred to as isoalkanes. Theoretically, the branches could be several carbon linkages long, but the isoparaffins in diesel oil are predominantly those with single carbon atom (methyl) branches. Some commonly occurring isoparaffins are isopentane, phytane, and pristane.

Naphthenes are often referred to as cycloparaffins or cycloaalkanes. Naphthenes are compounds usually made up of cyclopentane and cyclohexane subunits (having five and six carbon atoms, respectively, in a ring). Up to five rings may be joined together (or condensed) in the more complex molecules. Some naphthenes are cyclohexane, decalin, and fichtelite.

True aromatics contain only aromatic rings and side chains. They occur in diesel oil in various structures ranging from one to five aromatic rings. If more than one ring is present, the aromatics are nearly always condensed and have arrangements similar to those in the naphthenes. Some aromatics are benzene, toluene, trimethylnaphthalene, and pyrene. Figure A-6 shows some structural formulas of diesel oil components.

Kerosene

Kerosene is a straight-run petroleum distillation fraction (HSDB, 1987). It is composed of hydrocarbons containing 12 to 15 carbon atoms per molecule (Routh et al., 1971; Gruse and Stevens, 1960). Some of the chemical and physical properties of kerosene are listed in Table A-6. The foiling range of kerosene is 175 to 325 ^{o}C. It is insoluble in water and is miscible in alcohol (HSDB, 1987, ITII, 1976). The Chemical Abstracts Registry (CAS) number is 8008-20-6 (HSDB, 1987).

The approximate composition of kerosene from Ponca Petroleum of Oklahoma is shown in Table A-8. Althugh the kerosene constituents are predominantly saturated materials, there are also unsaturated compounds. Dicycloparaffins (naphthenes) also occur in substantial amounts in kerosene. Other hydrocarbons with aromatic and cycloparaffin rings in the same molecule, such as substituted indanes, occur in kerosene. The predominant structure of the dinuclear aromatics appears to be that in which the aromatic rings are condensed, such as napthalene; the isolated two-ring compounds, such as biphenyl, are only present in traces if at all (Speight, 1980). Kerosene contains no nitrogen, sulfur, or oxygen compounds (Butt, 1986).

Figure A-6 shows structural formulas for some components of kerosene.

Fate in Soil

The fate of diesel oil in the soil environment depends upon the physical and chemical properties of the diesel oil components. The aliphatic, unsaturated hydrocarbons, which compose the bulk of diesel oil, are insoluble and are preferentially adsorbed in soil minerals and organic matter. This fraction is considered relatively immobile. Degradation occurs through biological activity of soil microorganisms. The aromatic fractions of diesel oil and kerosene are more water soluble and may be leached in small amounts from the soil column into ground water (DOE, 1983).

As the dominant component of diesel oil, the aliphatic hydrocarbons determine the fate of most of the diesel oil released into the environment. Octane may be considered representative of this group of compounds. It is among the smaller molecules found in the aliphatic hydrocarbons, and its properties give a conservative estimate of the mobility of similar components of diesel oil. Octane has a low water solubility (0.66 ppm at 25 ^{o}C) and adsorbs readily to soils (Kd =110, calculated from Lyman et al., 1981). These properties result

in octane being relatively immobile in soils, where it is subject to biodegradation (rate constant = 0.11 per day) (Ladd, 1956). At application rates of a few pounds per acre, the aliphatic hydrocarbons have little potential for leaching from soils before significant biodegradation occurs.

The aromatic fractions of diesel oil include benzene, toluene, nethylbenzenes, and methylnapthalenes. In general, these compounds are relatively soluble in water. In a preparation of seawater and diesel oil at a ratio of 9:1 (volume:volume), 6.28 mg/L of the diesel oil was soluble, mainly as aromatic hydrocarbons (Anderson, 1975). Benzene has a solubility of 1,780 mg/L (at 25 ^{o}C). Tolune has a solubility in water of 470 to 515 Mg/L (Buikema and Hendricks, 1980). Adsorption of benzene by soils is moderate (Kd approximately 1.3, calculated from Mabey et al., 1982). Adsorption of toluene has been estimated to be approximately 5 times greater than that of benzene.

Aromatics that are water soluble and have low capacity for adsorption are likely to leach downward in the soil column. Aromatics undergo degradation at a lower rate than the aliphatics. The half-life for benzene is less than 1 month (Cogley et al., 1975 as cited in Buikema and Hendricks, 1980).

Diesel oil evaporates only very slowly when spilled on the soil. Losses from the soil result primarily from microbial degradation. Different fractions of the oil behave differently. The nonaromatic hydrocarbons are usually adsorbed to the soils and slowly evaporate or undergo biological degradation; they do not leach readily. Soluble aromatics, such as alkylated benzenes and naphthalenes, tend to be volatile but also tend to remain more stable and mobile in the soil column (DOE, 1983).

In the event of a spill, leaching hazard to a ground-water supply at a given depth below the soil surface depends upon the porosity of the soil and a characteristic of the petroleum product called its "residual saturation" (Davis et al., 1972). Soil porosity ranges from 25 to 50 percent in gravels and sands to 35 to 70 percent in silts and clays (Law Engineering Testing Company, 1982). Residual saturation, determined by the product's viscosity, is a measure of the tendency of the product to adhere to soil particles rather than to continue to move downward in soil under the force of gravity.

Residual saturation in petroleum products ranges fro 0.10 for gasoline to 0.20 for heavy fuel oil. Diesel oil has a residual saturation of about 0.15.

Davis et al. (1972) present an equation for determining the volume of soil required to immobilize an oil spill based on the product's residual saturation as follows:

$$V_{soil} \quad \frac{0.20 \times V_{oil}}{P \times S_R}$$

where:

V_{soil} - is the volume of soil in cubic yards required to immobilize the spill

V_{oil} - is the volume of the oil product in barrels (1 barrel = 42

gallons)

P - is the soil porosity (fraction of pore space), and

S_R - is the product's residual saturation

This spill equation can be applied to determine the possibility of ground-water contamination from a routine aerial application. Assuming an application rate for diesel oil of 20 gallons per acre and a soil porosity of 30 percent, the soil volume required for diesel oil would be:

$$\frac{0.20 \text{ x } (20/42)}{0.30 \text{ x } 0.15} = 2 \text{ cubic yards}$$

Assuming an application rate for kerosene of 0.015 gallons per acre as an inert in an herbicide formulation, the required soil volume would be:

$$\frac{0.20 \text{ x } (0.015/42)}{0.30 \text{ x } 0.13} = 0.0018 \text{ cubic yards}$$

One acre of soil contains 134.4 cubic yards of soil in the top 1 inch. Therefore, at the application rates described above, neither product is likely to move down through the soil below the top inch unless rain follows immediately after spraying. Therefore, ground-water contamination immediately following a spray operation is not likely to occur. However, if a spill of the same 20 gallons of diesel oil were to occur in an area where the water table is close to the surface, there is a possibility of contamination. Proper spill cleanup procedures should be followed immediately.

Areas most susceptible to ground-water contamination would be those with low porosity soils (gravels and sands), high water tables (i.e., close to the soil surface), and low populations of oil-degrading microorganisms.

The potential for runoff of diesel oil from soil is low based on the strong adsorption of octane to soils (Kd = 110, calculated from Lyman et al., 1981) and its rapid biodegradation (half-life = 6.3 days, based on a rate constant of 0.11, Ladd, 1956). Immediately after a heavy rainfall diesel oil was not detected (detection limit = 1 mg/L) in a stream adjacent to a site treated at 15 to 20 gallons per acre (Thofern, 1962, as cited in DOE, 1983).

Fate in Air

Aerial application of diesel oil at canopy height in forested areas could present a problem by evaporating while descending from the spray boom: diesel is volatile because of relatively high aromatic content. Evaporation reduces droplet size, thus contributing to drift potential. Evaporation of diesel oil would be much less than that of water, which is the predominant alternative carrier used in pesticide formulations.

Because of the relatively high volatility of diesel oil (2.07 mm Hg at 40 ^{o}C) and its aromatic constituents (95.2 mm Hg at 25 ^{o}C for benzene), transfer to the atmospheric environment from evaporation of spray droplets and evaporation for plant surfaces is probably. There is a slight possibility that diesel oil or kerosene might produce flammable vapors that could be hazardous, but these

vapors should not be a problem in forestry applications because the amounts sprayed are relatively low and they are not applied in a confined space.

Because of the hazards associated with the production of vapors from diesel oil and kerosene, handling and use should occur only in well-ventilated areas.

Fate in Water

Studies reported by DOE (1983) indicate that diesel oil applied to water first forms a partial film on the surface water. A portion of the acutely toxic volatile compounds may quickly evaporate from the film, while the remaining portion is adsorbed to particulates or is dissolved in water. Photooxidation acting on surface films can generate materials highly toxic to aquatic organisms (DOE, 1983). Surface oil is readily adsorbed on suspended particulates and may settle from the water column to the sediments (DOE, 1983). Blumer (1970, as cited in DOE, 1983) found that No. 2 fuel oil, incorporated into estuarine sediments after a spill, persisted for more than a year and spread in the form of oil-laden sediment beyond the original spill area.

Oil particles in water are decomposed mainly by aerobic microbiological processes (McCauley, 1966, as cited in DOE, 1983). The biochemical oxygen demand (B)D) is approximately 3.1 to 3.5 mg 0_2/mg oil (or about 2,500 to 2,800 mg 0_2/mL oil, assuming that the density of diesel oil is about 0.8 g/mL. Water temperature is important in determining the rates of decomposition and sedimentation (DOE, 1983).

The aromatic hydrocarbons are more soluble than the aliphatic compounds (1.78 x 10^3 mg/L for benzene and 535 mg/L for toluene, both at 25 ^oC). Some of the aromatics would be volatilized into the atmosphere before reaching surface waters (vapor pressure = 95.2 mm Hg at 25 ^oC for benzene). The half-life for volatilization of typical aromatics ranges fro 2 to 10 days, based on available values for the Henry's law constants for toluene and benzene (H_c = 6.66 x 1^{-3} atm)(m^3/mol) for tolune, H_c = 5.5 x 10^{-3} atm (m^3/mol) for benzene, from Mabey et al., 1982).

Fate in Plants

Diesel oil and kerosene are highly toxic to plants. The following description of the action of diesel oil on plants is taken from DOE, 1983:

Diesel oil readily wets plant surfaces and spreads as a thin film over leaf surfaces. Diesel oil penetrates the crowns of grasses where growth originates. It penetrates many other plants through stomata, because oil has a very low surface tension and is not barred from penetration as are most aqueous solutions (Van Overbeek and Blondeau, 1954). Diesel oil, therefore may increase the adsorption by the plant systemic herbicides.

Numerous workers suggest that an oil coat on leaves and stems will inhibit gas exchange and lead to death, but the data do not support this suggestion (Baker, 1970). Kerosene and diesel fuels are contact herbicides in their own right (California Department of Food and Agriculture, 1978), because of the toxic properties of the more volatile components.

Oil moves into intercellular spaces and in the process may interfere with translocation of metabolic products and nutrients in the plant (Baker, 1970). Oil does not penetrate cells unless the cells are injured (Van Overbeek and Blondeau, 1954). Toxicity varies according to the content of low boiling compounds, alkenes (unsaturated compounds), aromatic compounds, and acids. Phenolic acids and polycyclic aromatics are especially toxic to higher plants at low concentrations because of disruptive effects on cell membranes (Van Overbeek and Blondeau, 1954; Larson et al. 1977). Chronic injury also results from alkenes (Baker, 1970).

The mechanisms of cell injury and death are not clearly understood. Oil application depresses photosynthetic rates and depresses respiration rates to a lesser extent. As a result, respiration may exceed photosynthesis and lead to cell death (Wedding et al., 1952). Van Overbeek and Blondeau (1954) have described the symptoms of oil toxicity. The earliest symptom is darkening of your leaf tips, presumably because of fluid leakage into intercellular spaces. The darkening spreads to older leaves, and cells begin to lose turgor, resulting in plant drooping. Eventually cell membranes are disrupted, resulting in an increase in cell membrane permeability. Photosynthetic activity drops after chlorophyll is destroyed by bright sunlight. Photosynthesis is inhibited by oil deposition as low as 0.3 to 0.6 mg/cm^2 (leaf surface).

Bioaccumulation

A few constituents of diesel oil have some potential for bioaccumulation. The octanol-water partition coefficients (K_{ow}) are 10,000 for octane, 620 for toluene, and 135 for benzene (Mabey et al., 1982). The bioconcentration factors (BCF's) of these constituents were estimated. Using the K_{ow}'s and formula by Veith et al. (1979a in Spacie and hamelink, 1985), $\log BCF = 0.76 \log K_{ow}$ 0.23. The estimated BCF's were octane 646, toluene 78, and benzene 24. A bioconcentration factor of 12.6 has been estimated for benzene by Lyman et al. (1981).

In exposure studies to marine invertebrates, exposure to a 30-percent solution of the water-soluble fraction (about 2 mg/kg hydrocarbons) resulted in maximum tissue concentrations of 10 mg/kg in grass shrimp Palaemonetes pugio, with subsequent depuration to less than 0.2 mg/kg in 50 hours (Anderson, 1975). In the same study, in the clam Rangia cuneata had tissue concentrations of napthalenes of 100 to 150 mg/kg after exposure to 384 mg/L of No. 2 fuel oil in oil-water dispersions with depuration to approximately 0.2 to 0.3 mg/kg after 200 hours in oil-free water. The study revealed that the aquatic invertebrates could expel toxic components of oils from tissues, even after very high exposure levels (Anderson, 1975). The sublethal toxic effects of these levels of exposure were not examined.

Table A-1--Properties of malathion.

Purity	98.5 - 99.5 percent (analytical grade) 91.95 percent (technical grade)
Boiling point	156 °C (at 0.7 torr)[a]
Melting point	2.85 °C
Refractive index	1.4985 (25 °C)
Specific gravity	1.232 (25 °C)
Vapor pressure	1.25×10^{-4} mm Hg (20-25 °C)
Octanol-water coefficient	776
Solubility in water	145 ppm (20-25 °C)
Organic carbon partition coefficient	1800

[a]1 torr = 1/760 of an atmosphere.

Table A-2--Properties of carbaryl.

Purity	80 percent (Sevin sprayable formulation)
Melting point	142 °C
Specific gravity	1.232 (20 °C)
Vapor pressure	4.1×10^{-5} mm Hg (25 °C)
Solubility in water	40 mg/L (25 °C)
Octanol-water coefficient	651
Organic carbon partition coefficient	230

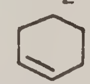
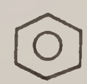
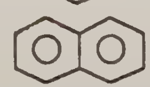
Table A-3--Properties of acephate.

Melting point	82-89 °C (technical)
Vapor pressure	2×10^{-6} mm Hg (25 °C)
Solubility in water	65 g/100 mL
Specific gravity	1.046 (2 lb a.i./gal)
Octanol-water coefficient	0.0428
Organic carbon partition coefficient	2.73

Table A-4--Properties of methamidophos.

Melting point	39-41 °C (for pure compound)
Vapor pressure	1×10^{-4} mm Hg (20 °C)
Solubility	Miscible with water and alcohol: 1% in kerosene; 10% in benzene or xylene
Specific gravity	1.31 for melted solid

Table A-5--Hydrocarbon classes and example

Class	Characteristic Carbon-Bonding	Example Hydrocarbons	Chemical Formula	Melting Point (°C)	Boiling Point (°C)
Alkanes	Open chain of C-C single bonds, saturated	Propane	$CH_3CH_2CH_3$	-187	- 42
		n-Hexane	$CH_3(CH_2)_4CH_3$	- 94	+ 69
Alkenes	Open chain of C=C double bonds, unsaturated	Propylene	$CH_3CH=CH_2$	-185	- 48
		1-Hexene	$CH_3(CH_2)_3CH=CH_2$	-140	+ 64
Alkynes (Acetylenes)	Open chain of C≡C triple bonds, unsaturated	Propyne	$CH_3C≡CH$	-103	- 23
		1-Hexyne	$CH_3(CH_2)_3C≡CH$	-132	+ 71
Cycloalkanes	Ring of C-C saturated bonds	Cyclopropane	CH_2-CH_2 / CH_2	NA	NA
		Cyclohexane		NA	NA
Cycloalkenes	Ring with at least 1 C=C double bond	Cyclopropene	$CH=CH$ / CH_2	NA	NA
		Cyclohexene		-104	+ 83
Aromatics	Benzene ring structure, which includes 6 carbon and 6 hydrogen atoms and equal bond lengths	Benzene		+ 6	+ 80
		Napthalene		+ 80	+218

Source: Routh et al., 1971.
NA = Not available.

Table A-6--Physical and chemical properties of diesel oil and kerosene.

Property	Diesel oil	Kerosene
Number of carbon atoms	10-25	12-15
Aromatic composition	30-35%	15-20%
Physical state	Oily liquid	Mobile, oily liquid
Color	--	pale yellow or water-white;
Odor	--	characteristic, slightly disagreeable
Boiling range	175-370 °C	175-325 °C
Flash point	85 °C	66-82 °C
Density	0.82 g/cc	0.80 g/cc
Vapor pressure	2.07 mm Hg (40 °C)	--
Vapor density	--	4.5
Solubility		
Water	Insoluble	Insoluble
Alcohol	Miscible	Miscible
Other petroleum solvents	Miscible	Miscible
Organic carbon partition coefficient (octanol)	5500	5500

Sources: HSDB, 1987; ITII, 1976; DOE, 1983; ROUTH et al., 1971; Bingham et al., 1979.

Table A-7--Estimated percent compositions of diesel oil and kerosene[a]

	Diesel oil	Kerosene
Normal paraffins	5.6	11.1
Isoparaffins (isoalkanes)	11.1	18.5
Napthenes (cycloparaffins or cycloalkanes)	46.3	50.0
Aromatics	33.3	20.4
Nitrogen, sulfur, and oxygen compounds	3.7	0

[a] Estimated from Butt (1986).

Table A-8--Composition of kerosene from Ponca Petroleum, Oklahoma, U.S.A.

Hydrocarbon Type	Volume percent
Alkanes (paraffins)	
Normal	23
Branched	16
Monocyclo-	32
Dicyclo-	11
Tricyclo-	0
Aromatics	
Mononuclear	15
Dinuclear	3

[a] Includes both alkylbenzenes and aromatic-cycloparaffin types.
Source: Speight, 1980.

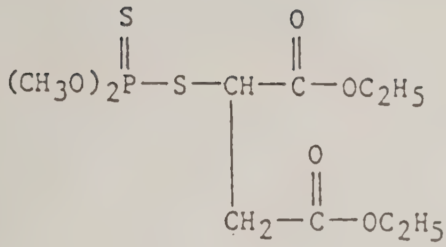


Figure A-1--Structure of malathion

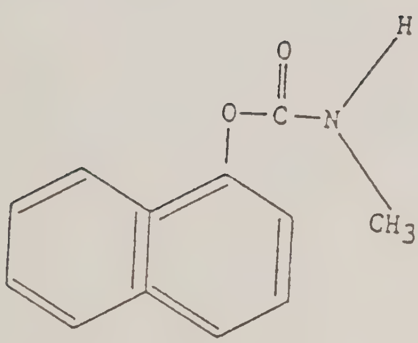


Figure A-2--Structure of carbaryl

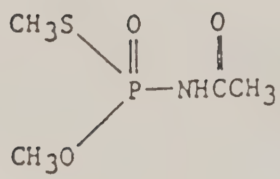


Figure A-3--Structure of acephate

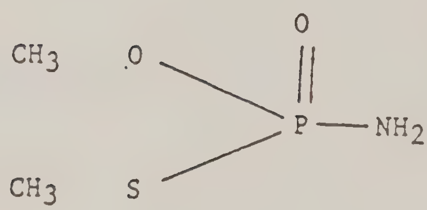


Figure A-4—Structure of Methamidophos

Figure A-5--Boiling Range and Range of Number of Carbon Atoms in Crude Oil Distillation Products

Gasoline
$(C_6-C_{12}$

Kerosene
$(C_{12}-C_{15})$

Diesel Oil
$(C_{10}-C_{25})$

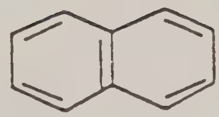
Gasoil (fuel oil)
$(C_{15}-\ \ )$

150 200 250 300 350 400

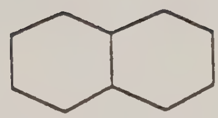
DEGREES CENTIGRADE

Source: Routh et al., 1971

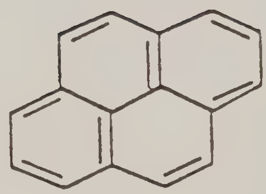
Naphthalene ($C_{10}H_8$)



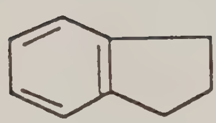
Decalin ($C_{10}H_{18}$)



Pyrene ($C_{16}H_{10}$)



Indane (C_9H_{10})



n-Dodecane ($C_{12}H_{26}$)

Figure A-6 Structural Formulas of Some Kerosene and Diesel Oil Constituents

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Appendix B

PROCEDURES FOR THE SELECTION OF DATA SETS FOR WORST-CASE RISK ANALYSIS: MUTAGENICITY/CARCINOGENICITY

BACKGROUND

The methods for cancer risk analysis using animal data have been reasonably well formulated. However, in the absence of rodent cancer data or with negative rodent cancer data, positive results from short-term tests for genotoxicity have been used as justification for either (1) questioning the adequacy of the rodent cancer studies or (b) recommending risk assessments for heritable mutations by way of germ cell damage in rodents.

The rationale for such a use of short-term assays rests with the close mechanistic and correlative association between carcinogens and mutagens (Brusick, 1987). It also assumes that agents defined by short-term tests as mutagens have the potential to induce similar damage in mammalian germ cells and that such damage could be transmitted to successive generations in the form of genetic disease or congenital malformations (Brusick et al., 1981).

DEFINITIONS

Often the meaning of technical terms are not universally consistent and without general agreement as to what they mean, arbitrary use of some terms or phrases may tend to increase confusion surrounding the analysis of a scientific issue. The five terms or phrases underlined in the above statement may be defined in several ways. Their meanings in this discussion are as follows:

Short-term tests--submammalian, mammalian *in vitro* cell culture or mammalian somatic cell tests measuring DNA alterations.

Genotoxicity--the process of chemical-induced damage to the DNA of an organism that will produce cell death, mutation, DNA alterations and repair, or cell transformation.

Heritable mutations--mutations that are induced at any germ cell stage in mammalian gametogenesis and that can be transmitted to and expressed in subsequent generations.

Germ cell damage--in rodents, this is measured by very specific types of assays. Germ cell damage may produce lethal or heritable effects; in this discussion, only those effects that are heritable are considered relevant to risk assessment. The two standard tests for assessment of germ cell damage in this context are the mouse specific locus test (SLT) and the mouse heritable translocation test (HTT).

Mutagens--chemicals capable of inducing gene or chromosome damage that is stable and survives cell division. Effects may be in somatic cells or germ cells.

NATURE OF THE DATA ENCOUNTERED IN DEVELOPING RISK ASSESSMENTS

The mutation and cancer data configurations of interest are summarized in Table B-1. The selection of a data set for use in making a risk analysis is based on the data most likely to provide the worst case estimate.

ISSUES AND RECOMMENDATIONS

The issues have been formulated as follows:

1. From the data sets shown in Table B-1, how does one support selection of data for the worst-case risk?

2. For chemicals with no germ cell mutagenicity studies and inconclusive or negative cancer studies, should positive short-term test results for genotoxicity assays be used as evidence in a worst-case analysis that a heritable mutation risk may exist at exposures lower than the MTD used to test for cancer?

Recommendations: Issue #1

In the cases where rodent cancer studies have been performed, these data should be used to set the human risk levels unless it can be shown from corresponding rodent germ cell data that statistically significant specific locus mutation or heritable translocation responses occur at comparable or lower exposures.

Rationale

The existing data base for chemicals that have been tested in rodents for carcinogenic as well as heritable mutation effects supports the judgment that carcinogenesis is the more sensitive to the two endpoints. Human cancer and mutational epidemiology information accumulated from atomic bomb survivors in Japan shows clear associations between dose and cancer but no mutations have been found. Radiation is mutagenic in rodents. The data in Table B-2 are used to support the sensitivity argument by comparing the results and effective dose levels for virtually all chemicals that have been tested for heritable germ cell mutation and have corresponding rodent cancer studies. Data from chemicals negative in both bioassay types are not included. Although all compounds listed were found to be carcinogenic, seven were clearly nonmutagenic at the highest dose tested and three were evaluated as inconclusive (no significant effect in the sample size examined). It is important to note that no compounds have been shown to induce heritable germ cell responses in rodents without concomitant carcinogenicity.

Potency comparisons (lowest effective daily dose for mutagenicity vs. tumor dose 50 [TD_{50}] daily dose for carcinogenicity, which is the dose estimated to result in 50 percent tumor-free animals at the end of the study) with chemicals that produced both effects showed that risk to cancer was found at lower average daily dose levels than risk to heritable mutation in all cases and for total cumulative dose for most chemicals. For some nonmutagens, the total applied dose was lower than the cumulative dose needed to achieve a TD_{50}. This is explained by the fact that mutation studies are conducted with single acute exposures and the total amount of material applied acutely will be less than that which could be applied by repeated exposures of lower doses.

There are many possible explanations for the observations that cancer is the more sensitive endpoint; for example, mammalian gonads are generally more protective from the systemic exposures by the blood-gonad barriers than somatic tissues preventing compound exposure. It also appears that the meiotic process associated with germ cell production is extremely effective in eliminating damaged DNA before it becomes part of mature spermatozoa or ova. This is probably accomplished by DNA repair or by selective elimination of damaged cells from the gene pool.

When cumulative exposures from chronic cancer studies (approximately 500 days) are compared to single total doses from mutation studies, a few of the chemicals (cyclophosphamide, methylmethane sulfonate, trenimon) appear to show greater activity for mutation than cancer. These examples are probably not exceptions but represent the bias encountered toward the mutation data. The following points illustrate three aspects of comparisons that would tend to enhance the apparent sensitivity of mutation assays:

Fractionation of Doses. Cancer studies are conducted with low daily doses given chronically while mutation studies are conducted generally with a single acute high dose. Occasionally, multiple dose studies for mutation are performed. When chemicals are tested for mutation using both single acute and subchronic applications, the results are often different.

Fractionated doses for mutation appear to result in a significant drop in mutation. Russell et al. (1982) have shown that 10 x 10 mg/kg doses of ethyl nitrosourea given over 10 weeks gives a much lower mutation frequency than a single dose of 100 mg/kg. Other findings indicate that, for some agents, the results for fractionated doses appear to be additive (Ehling, 1980; Ehling and Neuhauser-Klaus, 1984). In order to make the most conservative comparisons, the cumulative TD_{50} average (mg/kg) daily dose (roughly 500 days for a chronic study) from the rodent cancer studies was compared with either the lowest effective dose for mutagens or the highest dose tested for nonmutagens. Dose rate differences would tend to bias sensitivity toward the mutation data.

Route of Administration. Most of the mutation assays were performed using intraperitoneal (IP) injection of the test agent. This route of administration is believed to over-estimate risk because chemicals that are not readily absorbed from the GI tract following ingestion will be active by this route. Chemicals that would readily hydrolize to nonmutagenic forms under ingestion or gavage routes are also known to produce positive effects by the IP route. None of the cancer studies were conducted using intraperitoneal injection exposure. Chemicals such as nitrosoguanidine, ethylmethane sulfonate and methylmethane sulfonate would probably not be mutagenic in mice if administered via oral ingestion. The routes of exposure used would tend to bias sensitivity toward the mutation data.

Response Parameters. The dose levels used from the cancer studies represent the TD_{50}. The TD_{50} is not necessarily the lowest effective carcinogenic dose; it is used as a means of normalizing responses from different species and study designs. The doses used from positive mutation studies represent the lowest tested dose producing a statistically significant increase in either specific locus mutation or heritable translocation in mice. Studies defined as negative were of sufficient power to declare a noneffect. Studies defined as inconclusive showed no increase in mutation but the sample size examined was

insufficient to declare the chemical a clear negative. In either of the latter two cases, the dose shown was the highest dose tested. <u>Comparing the cancer bioassay TD_{50} dose to the lowest effective mutagenic dose would probably tend to bias the sensitivity toward the mutagenicity data</u>.

Thus, it is not surprising that for a few selected chemicals mutation risks may appear greater than cancer risks; however, if these compounds could be compared at the same dose rate and by a relevant route of exposure (oral ingestion or inhalation), it is very likely that the apparent sensitivity of the mutation endpoint would disappear.

<u>Recommendations: Issue #2</u>

Germ cell mutation data can be used for worst case risk analysis only when (1) no rodent cancer studies have been conducted and positive germ cell data (heritable translocation assay or specific locus mutation assay) are available, or (2) rodent cancer studies have been conducted producing negative results and positive germ cell data are available. Positive short-term test results are insufficient evidence for presumption of germ cell risk.

Rationale

As argued under Issue #1, genotoxins have a higher probability of expressing biological activity as carcinogens rather than inducers of heritable germ cell effects in rodents (Table B-2). All available data also support the fact that carcinogenic potential in rodents will be exhibited at lower (average daily or cumulative) doses than heritable mutagenicity for mutagenic carcinogens. Consequently, agents tested in rodents at the MTD that fail to elicit an effect as a somatic cell tumorigen are not going to produce heritable effects under similar exposure conditions in the intrinsically more resistant germ cells.

Occasionally, the toxicity data available to calculate worst-case risk may consist of chemicals with negative or inconclusive rodent cancer data and positive short-term test results for genotoxicity (excluding positive germ cell responses). The tendency might be to generate a worst-case by "assuming" that the short-term studies are adequate evidence that the chemical would induce heritable germ cell effects and therefore should be treated as a mutagen. This is not a supportable assumption based on the rationale supporting the recommendations for Issue #1 and an analysis of how well positive short-term test results predict germ cell mutagenesis in rodents.

Evidence that argues against the presumption that "a chemical that is not carcinogenic in rodents but is positive in short-term tests should be treated as a germ cell mutagen" comes from analyses of the predictivity of short-term genotoxicity assays for concomitant responses in rodent germ cells. Three independent analyses of the concordance values clearly demonstrate that one cannot accurately predict heritable genetic damage <u>in vivo</u> from single short-term assays (ICPEMC Committee 1, 1983; Russell et al., 1984; Bridges and Mendelsohn, 1986). Tables B-3 and B-4 give results from the EPA GeneTox data base in which the concordance between individual short-term tests and responses in either the mouse specific locus or the mouse heritable translocation assays are calculated. When the concordance values for any individual comparison are corrected for random assortment, none of the short-term test observed concordance values is statistically significant (Russell et al., 1984). This

finding precludes general extrapolation from a positive short-term test response to a presumption of effects in rodent germ cells.

Thus, a hope that one can develop a worst case risk analysis for heritable mutation with a compound that is not carcinogenic in rodents but has some positive short-term test results is not supported by the available data. Semianalytical weight-of-evidence approaches considering data from extensive batteries of short-term tests are available and may prove valuable in performing this type of hazard assessment. A better approach to establish a worst-case would be to establish the estimated risk from the cancer study assuming an effect at the upper bound of the 95 percent confidence limits. This would provide a suitable conservative worst-case assessment for nonthreshold effects. It would also prevent short-term test data from being inappropriately used in risk analysis.

CONCLUSIONS

The available data generated from rodent risk assessment assays on chemicals tested for cancer and mutation support the general practice of setting worst-case human risks for nonthreshold toxicity on the basis of estimated tumor induction. This practice is not only supported quantitatively by comparing lowest effective doses where both biological endpoints have been induced but is also supported qualitatively in that:

1. Chemicals that are effective carcinogens in rodent models have not been found to be mutagenic to the germ cells at comparable or even higher exposures.

2. No chemical has produced unequivocal heritable mutation in rodents that is not also carcinogenic and generally at lower exposures.

3. Humans exposed to a genotoxic carcinogen (radiation) showed significant increases in cancer but no evidence of induced germ cell mutation.

Extrapolation of positive responses from short-term nongerm cell mutagenicity studies to a presumption of effect or risk to germ cells is not supported by the available data. Positive short-term tests results should be used to support a presumption of carcinogenic potential.

Short-term assay data sets should be evaluated using a weight-of evidence approach.

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Table B-1 Bioassay Results and Data Selection for Risk Analysis

Rodent Cancer Studies	Rodent Germ Cell Mutation Studies	Selection of Data for Risk Analysis
Positive	Positive	Cancer Data
Positive	Negative or no data	Cancer data
Negative or no data	Positive	Mutation data
Negative or inconclusive	Negative or no data[a]	Estimated from upper bound of high dose Cancer data

[a] Short-term tests for genotoxicity show some positive effects.

Table B-2 Comparison of the Carcinogenic and Germ Cell Mutagenicity Activities of 20 Chemicals

Chemical	Rodent[a] Carcinogen	Rodent[a] Mutagen	Total Dose Applied (mg/kg) Cancer (ADD)[b]	Total Dose Applied (mg/kg) Mutation[c]	Most Sensitive Endpoint Avg. Daily Dose	Most Sensitive Endpoint Total Dose
Benzo(a)pyrene	+	-	1000 (2)	5000	C	C
Cyclophosphamide	+	+	3500 (7)	350	C	M
Diethylnitosamine	+	-	10 (.02)	119	C	C
7,12 Diemthylbenzanthracene	+	inc.	40 (.08)	10	C	C
Ethylmethane sulfonate	+	+	-	300	?	?
Ethlnitrosourea	+	+	-	250	?	?
Methylmethane sulfonate	+	+	17,500 (35)	20	M	M
Methylnitrosoguanidine	+	inc,.	1,000 (2)	50	C	C
Mitomycin C	+	+	.05 (.001)	5	C	C
Procarbazine	+	+	250 (.5)	400	C	C
Propylmethane sulfonate	+	+	-	800	?	?
Triethylene melanine	+	+	-	0.2	?	?
Trenimon	+	+	250 (.5)	0.13	M	M
Nitrogen mustard	+	+	5 (.01)	-	?	?
Captan	+	+	50,000 (100)	3000	C	C
Ethylcarbamate (urethane)	+	-	25,000 (50)	1750	C	C
Hexamethylphosaphamide	+	-	-	1989	C	C
Ethylene Dibromide	+	inc.	1500 (3)	167	C	C
1,2-Dibromo-3-chloropropane	+	-	2000 (4)	384	C	C
Nitriolotriacetic acid	+	-	112,500 (225)	3000	C	C

[a] Mouse or rat.
[b] (ADD) average daily dose required to produce TD_{50}.
[c] In mutation studies exposures are generally acute and thus Total Dose = ADD.
[d] C = cancer, M = mutation, ? = data gap.

Table B-3--Performance of Various Assays Relative to Specific-Locus-Test (SLT) Results

Assay Compared with SLT[a]	Concordance Observed	Concordance Calculated For Random Assortment[b]
Mouse spot test	91.7	77.8
Unscheduled DNA synthesis in testis	83.3	55.6
Micronucleus test	71.4	50.0
Plant gene mutations	61.5	60.4
Saccharomyces mutation	69.2	69.2
Dominant lethal	66.7	53.3
Drosophila sex-linked recessive lethals	62.5	55.5
Salmonella mutation	64.3	54.1
Sperm anomalies in treated males	66.7	61.1
Neurospora mutation	63.6	63.6
Plant chromosome anomalies	63.6	63.6

[a] Only assays that gave results for at least 20 of the chemicals tests by the assays

[b] On the null hypothesis.

Table B-4--Performance of Various Assays Relative to Heritable-Translocation-Test (HTT) Results

Assay Compared with HTT[a]	Concordance: Observed	Concordance: Calculated For Random Assortment[b]
Unscheduled DNA synthesis in testis	90.9[c]	64.5
Dominant lethal	76.5	64.0
SCE, animal cells, in vitro	91.7	77.8
Sperm anomalies in treated males	91.7	77.8
Drosphila heritable translocations	83.3	70.8
Micronucleus test	80.0	72.0
Salmonella mutation	71.4	65.3
Plant chromosome anomalies	92.3	92.3
Neurospora mutation	90.9	90.9
Drosophila sex-linked recessive lethals	83.3	83.3
Saccharomyces mutation	78.6	78.6
Male germ-cell cytogenetics	50.0	50.0
Host-mediated assay	78.6	80.6
Plant gene mutation	66.7	72.2

[a] Only assays that gave results for at least 20 of the chemicals tests by the assays.
[b] On the null hypothesis.
[c] Borderline of significance, P = 0.055.

Adapted by Russell et al., 1984.

APPENDIX G

Methods Used For Estimating Timber Volume Losses Caused By A Western Spruce Budworm Outbreak

The methods used for estimating the western spruce budworm-caused timber volume losses incorporate the use of two computer simulation models. Version 5.1 of the PROGNOSIS model for forest stand development (Stage 1973), basically a "tree-growing" model, is linked to a budworm damage submodel which was developed through the Canadian/U.S. (CANUSA) Spruce Budworm Research Program.

Tree data used in the analysis are obtained from the most current forest inventory of stand conditions. For National Forest System, State of Oregon, and private lands, data are taken from the latest Forest-wide inventory, most of which are updated every 10 years. Boise Cascade Corporation and Champion Timberlands supply their own tree data for their lands, as does the Bureau of Indian Affairs for Indian Reservation analysis units.

These inventory data are segregated by the appropriate land managers into components of an overall forest yield model. The five general categories of management needs are: (1) stands in need of regeneration; (2) stands in need of commercial thinning; (3) stands in need of precommercial thinning, (4) stands in need of overstory removal; and (5) stands where no management is planned. National Forests build an average stand for each model component in one of two ways: (1) by using tree data from the first three points of all forest inventory plots which represent a particular model component, or (2) by selecting a subset of the inventory plots which better represents the stands in a model component in the areas being analyzed. For National Forest lands, FORPLAN, a harvest scheduling model in use by the National Forests, is used to generate an optimum schedule of stand entries over time with the objective of maximizing present net worth of timber volume removed. An example of scheduled management needs for the Malheur National Forest is shown in Table G-I. The schedules of stand entries for State and private lands are provided by State personnel. Indian Reservation schedules are provided by the Bureau of Indian Affairs.

These inventory plot data are used as input to the stand prognosis model which was used to project volume growth over time until the final harvest. For each analysis unit, volume growth is projected for each model component using the stand prognosis model linked to the budworm damage submodel for each of several scenarios: untreated 10-year outbreak with light (U10L), moderate (U10M), or heavy (U10H) damage; treatment in the first year of visible defoliation in outbreaks projected to have light (T1 L), moderate (T1 M), or heavy (T1 H) damage, treatment in the second year of visible defoliation (T2 L, T2 M, T2 H), and so on (Table G-II). For all scenarios, it is assumed the length of the outbreak would be no longer than 10 years. Other parameters which are entered into the model include the amount of current year's defoliation for each year of the outbreak (Tables G-III through V) and the total amount of top-kill projected over the outbreak period. An example of values used for top-kill parameters for several treatment scenarios in an outbreak in which moderate damage is projected appears in Table G-VI. The volume at risk (the volume projected in a treated infestation less the volume projected for a similar untreated infestation) was estimated each decade that harvest was simulated. The total volume at risk over the rotation period (until final harvest and starting of a new stand) was then calculated for each combination of stand type, harvest type, harvest schedule, and insecticide treatment scenario. A numerical example of volumes generated by the combined models for a mixed-conifer stand on the Malheur National Forest is shown in Table G-VII.

Within each analysis unit, the acreage of each model component was totaled and multiplied by the per-acre volume at risk. These volumes were then added together to derive the total volume at risk for the analysis unit.

Table G-I

FORPLAN generated optimal mix of scheduled management needs (rows) for forest yield model components (columns) using a maximum present net worth objective function for the Malheur National Forest.

	Mixed Conifer 1/	Ponderosa Pine 2/	Lodgepole Pine 3/
Regeneration	Final harvest, decades 4-8	Final harvest, decades 4-8	Final harvest, decades 1-2
Commercial Thin	Overstory removal, decade 2; commercial thin, decade 4; final harvest, decade 6	Overstory removal, decade 1; commercial thin, decade 3; final harvest, decade 5	Overstory removal, decade 2; final harvest, decade 6
Overstory Removal	Overstory removal, decades 1, 2, 3; final harvest, decades 4, 5	Overstory removal, decades 1, 2, 3; commercial thin, decades 4, 5, 6; final harvest, decades 6, 7, 8	Final harvest, decades 1, 2
No Treatment in First Decade	Overstory removal, decade 2; commercial thin, decade 4; final harvest, decade 6	Overstory removal, decade 3; final harvest, decade 6	Overstory removal, decade 2; commercial thin, decade 6; final harvest, decade 8

1/ Stands consist primarily of Douglas-fir and grand fir.
2/ Stands may contain up to 20 percent Douglas-fir and/or grand fir.
3/ Stands may contain a small percentage of Douglas-fir and/or grand fir.

TABLE G-II

Insecticide treatment scenarios and the untreated scenarios with which they were compared to calculate volumes at risk for the 1988 environmental analysis of the western spruce budworm situation in the Pacific Northwest Region.

Treatment Scenario	Year(s) of Treatment 1/	Untreated Scenario	Length of Outbreak	Projected Damage
T1 L	1	U10L	10	Light
T1 M	1,4	U10L	10	Moderate
T1 H	1,4	U10L	10	Heavy
T2 L	2	U10L	10	Light
T2 M	2,5	U10L	10	Moderate
T2 H	2,5	U10L	10	Heavy
T3 L	3	U10L	10	Light
T3 M	3,6	U10L	10	Moderate
T3 H	3,6	U10L	10	Heavy
T4 L	4	U10L	10	Light
T4 M	4,7	U10L	10	Moderate
T4 H	4,7	U10L	10	Heavy
T5 L	5	U10L	10	Light
T5 M	5	U10L	10	Moderate
T5 H	5	U10L	10	Heavy
T6 L	6	U10L	10	Light
T6 M	6	U10L	10	Moderate
T6 H	6	U10L	10	Heavy
T7 L	7	U10L	10	Light
T7 M	7	U10L	10	Moderate
T7 H	7	U10L	10	Heavy

1/ These are the years in which insecticide treatment is projected (i.e., 2 indicates treatment in the second year that defoliation is visible during an aerial detection survey); note that some scenarios have two treatments during the course of the outbreak.

TABLE G-III

Western spruce budworm defoliation scenarios for insecticide treated and untreated Douglas-fir and grand fir in an outbreak in which light damage is predicted for the untreated scenario; 1988 analysis of the budworm situation in the Pacific Northwest Region.

	Treatment Scenario							
	U10L	T1 L	T2 L	T3 L	T4 L	T5 L	T6 L	T7 L
Year of Outbreak	Defoliation 1/							
1	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
2	40/50	35/45*	40/50	40/50	40/50	40/50	40/50	40/50
3	60/70	15/15	55/65*	60/70	60/70	60/70	60/70	60/70
4	70/75	25/25	15/15	65/70*	70/75	70/75	70/75	70/75
5	70/80	50/50	25/25	15/15	65/75*	70/80	70/80	70/80
6	70/75	60/60	50/50	25/25	15/15	65/70*	70/75	70/75
7	60/60	60/60	60/60	50/50	25/25	15/15	55/55*	60/60
8	50/50	50/50	50/50	50/50	50/50	25/25	15/15	45/45*
9	20/20	20/20	20/20	20/20	20/20	20/20	20/20	15/15
10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10

1/ The number before the slash is percent defoliation of current year's foliage on Douglas-fir and the number after the slash is for grand fir; an asterisk (*) indicates insecticide treatment in that year of the outbreak.

TABLE G-IV

Western spruce budworm defoliation scenarios for insecticide treated and untreated Douglas-fir and grand fir in an outbreak in which moderate damage is predicted for the untreated scenario; 1988 analysis of the budworm situation in the Pacific Northwest Region.

	Treatment Scenario							
	U10M	T1 M	T2 M	T3 M	T4 M	T5 M	T6 M	T7 M
Year of Outbreak	Defoliation[1/]							
1	10/20	10/20	10/20	10/20	10/20	10/20	10/20	10/20
2	40/50	35/45*	40/50	40/50	40/50	40/50	40/50	40/50
3	70/80	15/15	65/75*	70/80	70/80	70/80	70/80	70/80
4	85/90	30/35	15/15	80/85*	85/90	85/90	85/90	85/90
5	85/90	65/80*	30/35	15/15	80/85*	85/90	85/90	85/90
6	85/90	15/15	65/80*	30/35	15/15	80/85*	85/90	85/90
7	85/90	30/35	15/15	65/80*	30/35	15/15	80/85*	85/90
8	50/50	65/80	30/35	15/15	45/45*	30/35	15/15	45/45*
9	20/20	20/20	20/20	20/20	15/15	20/20	20/20	15/15
10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10

1/ The number before the slash is percent defoliation of current year's foliage on Douglas-fir and the number after the slash is for grand fir; an asterisk (*) indicates insecticide treatment in that year of the outbreak.

TABLE G-V

Western spruce budworm defoliation scenarios for insecticide treated and untreated Douglas-fir and grand fir in an outbreak in which heavy damage is predicted for the untreated scenario; 1988 analysis of the budworm situation in the Pacific Northwest Region.

	Treatment Scenario							
	U10H	T1 H	T2 H	T3 H	T4 H	T5 H	T6 H	T7 H
Year of Outbreak	Defoliation[1/]							
1	20/30	20/30	20/30	20/30	20/30	20/30	20/30	20/30
2	50/90	45/85*	50/90	50/90	50/90	50/90	50/90	50/90
3	80/99	15/15	75/94*	80/99	80/99	80/99	80/99	80/99
4	100/100	40/40	15/15	95/95*	100/100	100/100	100/100	100/100
5	100/100	90/90*	40/40	15/15	95/95*	100/100	100/100	100/100
6	100/100	15/15	90/90*	40/40	15/15	95/95*	100/100	100/100
7	100/100	40/40	15/15	90/90*	40/40	15/15	95/95*	100/100
8	80/99	90/90	40/40	15/15	70/89*	40/40	15/15	75/94*
9	50/50	50/150	50/50	40/40	15/15	50/50	40/40	15/15
10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10

1/ The number before the slash is percent defoliation of current year's foliage on Douglas-fir and the number after the slash is for grand fir; an asterisk (*) indicates insecticide treatment in that year of the outbreak.

TABLE G-IV

Amounts of top-kill projected on Douglas-fir and grand fir for several treatment scenarios of a western spruce budworm outbreak in which the predicted damage for an untreated 10-year outbreak is classified as moderate.

	Treatment Scenario						
	U10M	T2 M	T3 M	T4 M	T5 M	T6 M	T7 M
	70/.20 1/	.00/.00	.00/.00	.17/.02	.47/.04	.67/.08	.70/.20
Douglas Fir 2/	.77/.11	.00/.00	.00/.00	.25/.02	.55/.04	.75/.07	.77/.11
	68/.10	.00/.00	.00/.00	.05/.01	.35/.02	.55/.04	.68/.10
	79/.06	.00/.00	.00/.00	.05/.01	.35/.02	.55/.04	.79/.06
Grand Fir	91/.11	.00/.00	.00/.00	.35/.01	.65/.02	.85/.04	.91/.11
	86/.09	.00/.00	.00/.00	.26/.01	.56/.02	.76/.04	.86/.09

1/ The number in front the slash is the projected proportion of trees that will experience top-kill; the number after the slash is the projected average proportion of the total tree height that will be killed. 2The top row after each tree species shows projected levels of top-kill for trees 0 to 23 feet tall, the middle row for trees 23 to 46 feet tall, and the bottom row for trees taller than 46 feet.

Table G-VII

Timber volumes (board feet) projected by a combined stand prognosis/budworm damage model for several insecticide treatment scenarios for a mixed conifer stand on the Malheur National Forest.

	Insecticide Treatment Scenario									
Decade	**U10M 1/**		**T4 M**		**T5 M**		**T6 M**		**T7 M**	
1980	16332	0	16332	0	16332	0	16332	0	16332	0
1990 2/	16552	15601	17004	1495	16849	15428	16682	15572	16554	15602
2000	1452	0	3092	0	2208	0	1713	0	1452	0
2010	2315	0	5494	0	3557	0	2946	0	2315	0
2020 3/	4025	858	8558	2161	5651	1387	4196	1157	4025	858
2030	4632	0	8883	0	6159	0	4561	0	4632	0
2040 4/	6860	6637	11448	11218	8416	8183	7034	6745	6859	6637
Total Volume Removed		23096		28274		24998		23474		23097

1/ Numbers in the first column under each treatment scenario heading are the standing board foot wood volumes per acre at the beginning of each decade; the second column shows the amount of volume removed each decade.
2/ Overstory removal done this decade.
3/ Commercial thinning done this decade.
4/ Regeneration (final) harvest done during this decade.

APPENDIX H

Monitoring Of Effects Of Sevin-4-Oil

Abstract

In June 1979, Sevin-4-Oil was sprayed on 30,000 acres of forest on the Warm Springs Indian Reservation to control a spruce budworm infestation. Effects of the insecticide on fish and aquatic invertebrates were monitored at ten sites (three controls included) on seven streams. Spray cards indicated that Sevin-4-Oil entered the Warm Springs River, Butte Creek, and Wilson Creek. In a 12-hour period following spraying, 322,000 invertebrates drifted past monitoring sites on the Warm Springs River; 1,200 on Butte Creek. Little drift occurred in Wilson Creek. The insect orders Ephemeroptera, Diptera, Plecoptera, and Trichoptera comprised over 99 percent of the drift in both streams. All four orders decreased significantly (P.05) in post-spray bottom samples in the Warm Springs River, whereas in Butte and Wilson Creeks only, Ephemeroptera decreased significantly. Ephemeroptera and Diptera also decreased significantly in some control streams, but Plecoptera increased significantly in two control streams. Total invertebrates decreased significantly on the Warm Springs River, whereas no significant changes occurred in control streams.

The mean acetylcholinesterase activity of rainbow trout exposed to Sevin in the Warm Springs River was significantly (P.01) less (18 percent depression) than that of the control group. Catch-per-unit effort (CPUE) was greater in prespray sampling than in post-spray sampling at all sites, including controls. Increased CPUE's in postspray sampling probably resulted from reduced streamflows which increased electrofishing efficiency. The acetylcholinesterase and CPUE results suggest that no direct fish mortality or population reduction can be attributed to the spraying program.

Introduction

In June and July of 1979, the Bureau of Indian Affairs (BIA) and the USDA Forest Service (USFS) conducted a western spruce budworm (Choristoneura occidentalis) control program on the Warm Springs Indian Reservation in north-central Oregon. Sevin-4-Oil, a carbamate insecticide, was aerially sprayed on 30,000 acres of forest. Since Sevin can be toxic to fish and aquatic invertebrates, the U.S. Fish and Wildlife Service (FWS) was contracted to monitor the effects of the spray. Prespray data on invertebrate and fish populations in seven study and three control sites were compared to postspray data to evaluate the effects of the spraying program.

Study Area

The spray area is located in the northwest section of the Warm Springs Indian Reservation. Ten sampling sites, including three controls, were established for spray monitoring. An unnamed stream was designated No Name Creek. Normally, in a monitoring program of this type, three sampling sites are selected for each stream studied: a site within the spray area, an upstream control, and a site downstream of the spray area. In this study, however, control sites were selected on tributary streams outside the spray area because monitored streams originated within the spray area. An effort was made to select control sites similar in habitat and fish composition to the other sites. When possible, fish and invertebrates were sampled at the same location, but in some instances, stream conditions made it necessary to select separate sites.

Buffer zones extending 100 feet from both sides of the stream were marked prior to spraying on all monitored streams within the spray area. Buffer zones were to be excluded from spraying.

Nonanadromous fish species present in the spray area include rainbow trout (Salmo gairdneri), Dolly Varden (Salvelinas malma), eastern brook trout (Salvelinus fontinalis), sculpins, (Contus sp.) and dace (Rhinichthys sp.). Anadromous species present are chinook salmon (Oncorhynchus tshawytscha), and steelhead trout (Salmo gairdneri gradeneri). The insect orders Diptera, Trichoptera, Plecoptera, and Ephemeroptera comprise the majority of the aquatic invertebrates in the spray area.

The Warm Springs River and Beaver Creek rate first and second respectively in terms of anadromous fish production on the Reservation. The Warm Springs River is a major producer of spring chinook in the Deschutes River system; escapements as high as 2,500 fish were documented in 1978 by the FWS. The major spawning area for chinook in the Warm Springs River occurs in the 8 miles below Site 6B. In Beaver Creek, major chinook spawning occurs in the 2 miles of stream above Site 1B.

Spray Monitoring

Methods

Spray cards were placed along streams in the spray area to detect spray entering the streams. Generally, about eight 3- x 5-inch oil-sensitive cards were spread over a 0.5-mile section of stream near the site being monitored. Spray droplets hitting the cards appeared as white dots.

Results

During the spraying period, spray was actually applied on 9 days. Spray cards on Butte Creek and Wilson Creek were hit lightly on June 20 and 23 respectively, and cards on the Warm Springs River were hit heavily on June 22, and again on June 25.

Discussion

Although the terms lightly and heavily were used to describe the relative amount of spray hitting the cards, they may not actually reflect the relative concentration of Sevin in the stream because of the limited section of stream monitored. However, knowledge of the mere presence or absence of spray on the cards was useful in relating the biological monitoring results to effects of the spray. The following sections show that abnormally high invertebrate drift and acetylcholinestease depression occurred immediately after Sevin entered the streams.

Fish Population Monitoring

Methods

Six sites were chosen for fish monotoring: 1B, 2B, 3B, 4B, 6B, and 7F. Site 3B on Indian Creek was a "similar stream" control as described in the spray monitoring section.

Two methods were used to evaluate the effect of insecticide drift on fish populations: (1) a comparison of prespray and postspray fish abundance; and (2) measurement of brain acetylcholinesterase activity in rainbow trout.

Fish Abundance

Prespray sampling was conducted during the first 2 weeks in June, and postspray sampling during the second week of July. Stream sections 200-feet long were marked and blocked in both ends with 0.25-inch mesh seines to prevent escapement of fish. A Smith-Root Model VII backpack shocker was used to sample the fish populations. Salt blocks were used to enhance conductivity in some streams. One person operated the shocker, while one or two people dipnetted stunned fish. Fish were held until completion of shocking, and then counted, identified, and redistributed along the stream section. Conditions, such as the number of dipnetters and use of salt blocks, were duplicated for the postspray sampling.

An abundance index, catch-per-unit-of-effort (CPUE), was calculated for each site by dividing the number of fish caught by the seconds of electrofishing effort. CPUE values were used in comparing prespray and postspray abundances.

Acetylcholinesterase Comparison

Rainbow trout (mean length 3.75 in) were monitored for acetylcholinesterase depression in Butte Creek (2B), Warm Springs River (7F), and No Name Creek (8I), a control stream. Fish were held in liveboxes, constructed of 0.5-inch hardware cloth which allowed fish to feed on insects drifting through. Fish were placed in the streams several days before spraying so that they could acclimate to water conditions, and to allow the removal of nonspray-related mortalities. If a stream was hit with spray, as indicated by spray cards, the fish were observed for mortalities and behavioral changes, i.e., lethargy, whirling, etc. If a heavy hit was incurred, the heads of 20 fish from the livebox were dissected, wrapped in aluminum foil, and frozen on dry ice. The samples were air-freighted to Fort Collins, Colorado, where Dr. George Post, a private consultant, analyzed them for acetylcholinesterase depression. He used a modification of the Hestin procedure (Augustinsson, 1957), which measures the amount of acetylcholine hydrolized by 0.2 mg of brain tissue in 30 minutes. The mean brain acetylcholinesterase level of the control group was compared to the mean level in the spray hit group. The differences were compared with the Student-t test at the 95 percent confidence level.

Results and Discussion

Fish Abundance

Catch-Per-Unit-of-Effort for salmonids and nonsalmonids was greater in postspray samples than in prespray samples in all streams monitored. Increases ranged from 7 to 19 percent for Warm Springs River (6B), Wilson Creek, Butte Creek, and Beaver Creek. CPUE increased 115 percent at Site 7F on the Warm Springs River, and 91 percent on the control stream.

Two explanations for the increase in CPUE are possible. Streamflow decreased considerably during postspray sampling, and may have resulted in the increased CPUE's because electrofishing efficiency is greater in reduced flow situations (Beyerle and Cooper 1960). Immigration into the study sites could also have resulted in increased CPUE's. However, Shetter (1937), Shuck (1945), and Miller (1957) reported that resident salmonids remain in their home areas for some or all of their lifetimes, and Stauffer (1972) reported that downstream movement of rainbow is generally over by June or July. Previous work has shown little or no movement of resident or anadromous salmonids in the Warm Springs River system in late June and July. Most of the increase in CPUE is attributed to an increase in sampling efficiency in the postspray period.

Site 7F on the Warm Springs River probably received the highest level of Sevin. If the hit had been severe, fish mortality would have been expected. However, none occurred. CPUE data indicate that no decrease in the standing crop of fishes occurred at this site; an index of .056 fish/second for the postspray sample compared to .026 fish/second for the prespray sample indicates an increase of 115 percent. A comparison of the rate of increase at Site 7F (115 percent) with that of control Site 3B (91 percent) further substantiates the belief that mortality did not occur. If a large fish kill had occurred at Site 7F, the rate of increase would be expected to be less than that of the control.

No immediate effects of the spray were observed in fish populations in Butte Creek and Wilson Creek, both of which were lightly hit. Increase in postspray CPUE's for these streams were comparable to the other nonhit streams, indicating no measurable decrease in fish density.

Because of the influence of streamflows on electroschocking efficiency, small changes in fish density were undetectable. However, if severe mortalities had occurred, a substantial decrease in CPUE would have been expected in contrast to that of the control stream.

Acetylcholinesterase Comparisons

None of the trout held in liveboxes appeared stressed at any time, including those at Butte Creek which were placed in a 2.0-2.5 fps current for 0.5 hours on a day when Sevin entered the stream. Also, no wild trout were observed in distress at any time.

The heaviest insecticide drift occurred in the Warm Springs River above Site 7I. Fish held at this site and those from the control site on No Name Creek (8I) were sent to Dr. Post for acetylcholinesterase analysis. The mean brain acetylcholinesterase activity of 1.67 umol f/r the Warm Spring group was significantly (P.01) different from the mean value of 2.03 umol for the control group. This represents an acetylcholinesterase activity depression of 18 percent for the Warm Springs group.

The 18 percent acetylcholinesterase depression attributed to the spraying is near the low end of depression ranges found in two Maine studies where Sevin was used to control spruce budworm. Hulbert (1978) reported a range of 7 to 58 percent acetylcholinesterase depression for landlocked salmon (Salmo salar) and a range of 11 to 37 percent for brook trout (Salvelinus fontinalis). Haines (1979 unpublished) reported depressions ranging from 15 to 34 percent young-of-the-year brook trout. These fish, used in an on-site bioassay, suffered no mortalities associated with the spraying. In a third Maine study where Sevin was applied at half the usual dosage on two different dates, acetylcholinesterase levels in brook trout from treated streams were not significantly different (P.05) from levels in controls, although mean acetylcholinesterase values declined slightly over a 3-week period (Gibbs et al., 1979).

To determine the effect of acetylcholinesterase depression on a fish's stamina, Post and Leasure (1974) calculated activity indexes for rainbow trout subjected to different concentrations of Malathion, an organophosphate pesticide which, like carbamates, causes acetylcholinesterase depression. The activity index was calculated by adding the time it took 25 percent of a group of fish to be forced through a stamina tunnel, (velocity = 0.875 fps) to the time it took the remaining 75 percent to be forced through. The group which had a mean acetylcholinesterase depression of 18.5 percent had an activity index equal to 97.7 percent of the control group's index. In groups subjected to higher concentrations of the pesticide, an acetylcholinesterase depression of 49.4 percent corresponded to an activity index of 66.3 percent, and a depression of 71.9 percent corresponded to an index of 29.0 percent. The near normal activity index (97.7 percent) of the group having an acetylcholinesterase depression similar to that of the

rainbow trout in this study (18 percent) concurs with observations that the fish always appeared normal.

Dr. Post concluded that "there should be little or no lasting effect of the Sevin spraying to rainbow trout **held in the stream at Station 7I."** Only one group of fish was analyzed at one site at one point in time. Other AchE studies have shown that AchE depressions are sometimes lower 1 week after spraying than 1 day after.

It would not be correct to say that Dr. Post concluded "that survival of the fish in the Warm Springs River system was not significantly affected by spraying."

Based upon prespray and postspray abundance comparisons, and the low level of acetylcholinesterase depression in fish from a heavily hit stream, it was concluded that fish populations in the sprayed area were not directly affected by the spraying of Sevin.

Invertebrate Monitoring

Methods

Invertebrate monitoring was conducted at eight sites to determine the direct effect of spray operations on insect life. Sites 1B, 2B, 4B, 6B, and 7I were spray sites; sites 3B, 5I, and 8I were controls.

Invertebrate drift was measured to determine the immediate effect of the spraying. Invertebrates were collected by placing a 1-square-foot Surber sampler in the current for periods ranging from 15 minutes to 3 hours. In one instance (Site 7I) a 10-inch diameter plankton net was used in addition to the Surber sampler. The plankton net was placed in a deep, swift portion of the stream, and the Surber in a slower side channel. Drift rates were standardized by calculating the number of invertebrates per hour.

One week prior to spraying, drift samples were collected at invertebrate sampling sites 1B to 8I. During the spray period, drift samples were collected at sites closest to the sprayed area. An attempt was made to obtain at least one sample before spraying commenced. Samples were then collected about every hour until spraying ceased and it was evident invertebrates were not being affected, or when the drift rate returned to prespray levels.

In two instances when Sevin entered the stream, sample drift rates were expanded to calculate the number of insects drifting past a sample site in the entire stream channel. Estimates were calculated as follows:

$$\frac{\text{Number of insects in stream channel}}{\text{Hour}} = \frac{\text{Number of insects in sampler}}{\text{Hour}} \times \frac{\text{Stream flow (cfs)}}{\text{Sampler filtering rate (cfs)}}$$

Effects of the spraying were also evaluated by comparing the number and weight of invertebrates present before and after spraying. Three replicate bottom samples were taken in riffle areas at invertebrate sites with a 1-square-foot Surber sampler during three periods: on June 6 and 7, 1 week prior to spraying; on July 17 and 18, about 2 weeks after completion of spraying; and on October 2, 3, and 4 about 3 months after spraying was completed.

Depending upon available time, drift and bottom samples were either picked on-site, or in the laboratory, and then preserved in 10 percent formalin. Invertebrates were later transferred to 70 percent ethanol, and identified to order, counted, and weighed to the nearest mg. Trichoptera were removed from cases before weighing. A few large drift samples were subsampled by a factor of one-tenth.

Following standard procedures, data was transformed to $\ln(x + 1)$, and a Student-t test at the 95 percent confidence level was used to test for significant differences between prespray and postspray samples.

Results And Discussion

Drift Sampling: Abnormally high invertebrate drift was apparent at three of the sites: Site 2B on Butte Creek on June 20, and Sites 6B and 7I on the Warm Springs River on June 22.

Invertebrate drift at Site 7I on the Warm Springs River, as sampled in a slow (1 fps) side channel, increased from a prespray level of 13/hour at 0500 hours to a high of 740/hour at 0615 hours, about 1 hour after spraying commenced. The rate declined rapidly to 285/hour by 0800 hours and then more slowly to 45/hour by 1600 hours. Over 99 percent of the invertebrate drift was composed of the insect orders Ephemeroptera, Diptera, Plecoptera, and Trichoptera. Insect drift peaked at 0615 hours for all orders except Trichoptera, which peaked at 1015/hours. The highest drift rate was exhibited by Ephemeroptera (356/hour), followed by Diptera (291/hour), Plecoptera (99/hour), and Triachoptera (32/hour).

Estimates of the number of insects which drifted past Site 7I in the entire stream channel from 0400 to 1600 hours were taken. Two estimates are given: one from the Surber sampler placed in the slow side channel; the other from the plankton sampler in the

main channel. Summation of the insect drift for 1-hour intervals yields the following estimates (in thousands of insects) for the period 0400 to 1600 hours: 102-141 Ephemeroptera, 82-110 Diptera, 76-99 Plecoptera, and 15-19 Trichoptera for a total of 302-342 thousand insects.

Similarly, high drift rates were observed at Site 6B on the Warm Springs River. The Surber sampler rate declined from a high of 1,126 invertebrates/hour at 0630 hours to 156/hour at 1630 hours.

Invertebrate drift at Site 2B on Butte Creek on June 20 was considerably less than that which occurred on the Warm Springs River. Drift on Butte Creek increased from 2/hour at 0530 hours, to 29/hour at 0745 hours, about 2.5 hours after spraying started, and declined to 12/hour by 1200 hours. An estimated 1,200 insects drifted past Site 2B from 0400 to 1600 hours. Of these, Diptera comprised 43 percent, Ephemeroptera 26 percent, Trichoptera 26 percent, and Plecoptera 5 percent. Dipterans predominated the drift initially, but by 1000 hours, ephemeropterans and trichopterans predominated.

The immediate effect of Sevin on stream invertebrates is apparent from the estimated 1,200 insects which drifted past Site 2B on Butte Creek and 302,342 thousand insects which drifted past Site 7I on the Warm Springs River in a 12-hour period following spraying. In both instances, the insect drift rate peaked within 2 hours after spray cards indicated Sevin had entered the streams.

Bottom Sampling: Control streams exhibited different monthly patterns from June to October, but in no instance were the differences significant. The only significant change in streams within the spray area occurred on the Warm Springs River at Site 6B, where the numbers of total invertebrates in July and October samples were significantly less than in June samples.

Four insect orders were examined separately: Ephemeroptera, Diptera, Plecoptera, and Trichoptera. Ephemeropterans in control streams exhibited two different patterns . Ephemeropterans increased significantly in number from June to October in Cedar Swamp Creek, while they decreased significantly in Indian Creek (number and weight) and in No Name Creek (weight). In the spray area streams, ephemeropterans decreased significantly in Butte Creek in July (weight), in Wilson Creek in October (number), in Warm Springs River at Site 6B in July (number and October (number and weight), and in Warm Springs River at Site 7I in October (number).

Dipterans exhibited some small but significant changes in control and spray area streams. Two opposing changes occurred in control streams; dipterans increased in Indian Creek (weight) in October, but decreased in No Name Creek (number and weight) in October. Dipterans in the Warm Springs River at Site 6B decreased in number and weight in October.

Plecopterans in control streams either remained constant or increased from June to October; they increased significantly in Indian Creek in October (weight) and in Cedar Swamp Creek in July (weight) and October (number and weight). Plecopterans on the Warm Springs River at Site 6B decreased significantly in October (number).

Trichopterans in the control streams showed some changes in number and weight from June to October, but none of these differences were significant. Trichopterans decreased significantly on the Warm Springs River at Site 6B in October (weight) and increased significantly at Site 7I in July (weight).

Not all the reductions in invertebrate density which occurred within the spray area can be attributed to the application of Sevin. Because insect densities change naturally as adults emerge and young hatch, spray-related changes must be distinguished from natural ones. Establishing what natural changes have occurred becomes difficult when population changes in the control streams differ. For example, the significant decrease in Ephemeroptera which occurred on Butte Creek, Wilson Creek, and the Warm Springs River cannot be totally attributed to the spray, because ephemeropterans decreased significantly in two control streams but increased significantly in the third. Likewise, the decrease in Diptera in the Warm Springs River cannot be solely attributed to the effects of Sevin because one control increased, while another decreased.

Effects on Trichoptera were also not clearly discernible because trichopterans increased on the Warm Springs River at the site within the spray area (7I) while decreasing at the downstream site (6B).

The greatest contrast between spray area streams and control streams occurred for the order Plecoptera. Plecopterans decreased significantly at Site 6B, downstream of the spray area, while they increased significantly in two control streams. The number of total invertebrates also decreased significantly at Site 6B, whereas no significant changes in total invertebrates occurred in control streams.

Several investigators studied the effects of Sevin on stream invertebrates in Maine. Trial and Gibbs (1978) attributed short-term reductions of Ephemeroptera, Diptera, and Plecoptera to the application of Sevin. Within 2 months, Diptera and Ephemeroptera

populations had returned to prespray levels, but Plecoptera populations had not. Courtemanch and Gibbs (1977 unpublished, cited by Trial 1979) found that samples from some streams in the previous study were devoid of Plecoptera 1 year after Sevin was applied. Followup studies showed that Plecoptera had recovered by the second year in terms of number of individuals and number of taxa, but the three genera which were most numerous prior to spraying were markedly absent (Trial 1978); these conditions persisted during the third year after spraying (Trial 1979).

In our study, Plecoptera appears to be the most affected invertebrate order. It is notable however, that the mean number of Plecoptera at Site 6B on the Warm Springs River was the same in July as it was in June, and that the reduction was not observed until October, when control streams showed an increase. This suggests that Plecopteran reproduction may have been affected.

Because the reproductive potential of insects is high, it is unlikely that reductions in biomass would persist. However, as some Maine studies have shown, certain insects are more susceptible to the pesticide than others, and the composition of the postspray biomass may differ from that of the prespray biomass for some time. It would be difficult to predict what effect, if any, this could have on fish growth.

Aside from the difficulty of distinguishing spray-related effects from natural fluctuations in invertebrate density, it is apparent from the dead and moribund insects in the drift following spraying that Ephemeroptera, Diptera, Plecoptera, and Trichoptera are all affected. It is also apparent that the mortality occurred only on days when spray cards indicated that Sevin had entered the streams. Thus, adequate buffer zones should be established along streams within a spray area to reduce the danger of spray drift into the streams.

Theory and Use of Acetylcholinesterase Activity for Estimating the Effect of Carbamate Insecticides on Animals:

All higher animals, including fish, use acetylcholine to bridge the muscle nerve synapse for muscle contraction. Acetylcholine is secreted at the muscle-nerve juncture so the nerve impulse can continue into the muscle and stimulate muscle contraction. Excess acetylcholine at the muscle-nerve synapse is destroyed by the enzyme, acetylcholinesterase, otherwise muscles would remain in a state of continued contraction until completely fatigued. Reduction of acetylcholinesterase activity, because of its combination with insecticides such as the carbamates, in effect reduces the destruction of excess acetylcholine at the muscle-nerve synapse and muscle contraction until completly fatigued. Reduction of acetylcholinesterase activity, because of its combination with inscticides such as the carbamates, in effect reduces the destruction of excess acetylcholine at the muscle-nerve synapse and muscle contraction no longer functions properly. If too much acetylcholinesterase is bound by carbamate insecticides, muscle function, including heart and other vital muscles will be reduced, possibly to the point where the animal can no longer live. Small reductions in acetylcholinesterase activity will cause moderate muscle malfunction, usually manifested as loss of physical strength. There seems to be a quantitative reduction of physical strength in fishes when there is a quantitative reduction in acetylcholinesterase activity (Post, G. and R.A. Leasure, 1971).

The measurement of acetylcholinesterase activity in any body tissue of an animal following contact with carbamate or organophosphate insecticides is a way of assessing the quantitative effect of the insecticide. Brain tissue acetylcholinesterase activity is useful for this purpose.

There are several biochemical methods for estimating loss of acetylcholinesterase activity in animal tissues. The method of Hestrin is well adapted for estimating loss of acetylcholinesterase activity in the brain tissue of fish or other animals following their contact with carbamate insecticides such as Sevin. The Hestin procedure and its modifications actually measures the actylcholinesterase activity of a known quantity (0.2 milligrams) of brain tissue on a known quantity of acetylcholine when incubated at 25°C (77°F) for 30 minutes. The modified Hestin procedure used for surveying animal populations following environmental use of either carbamate or organophosphate insecticides is given by Gluiok, D. editor, Methods of biochemical analysis, Volume 5, pages 43-46. Interscience Publishers Inc. New York City, NY.

Interpretation Of Results

The mean brain Acetylcholinesterase activity of rainbow trout from the Sevin-sprayed area was 82.3 percent of the mean brain acetylcholinesterase activity of fish kept as control (nonsprayed area).

The lowest brain acetylcholinesterase found among fish from the sprayed area was 52.2 percent of the mean activity in the control fish, and 63.9 percent of the control fish with the lowest (normal) brain acetylcholinesterase activity.

The data indicate moderate reduction in brain acetylcholinesterase activity among fish subjected to Sevin, when compared to nontreated fish.

The treated fish with the lowest brain acetylcholinesterase activity may have lost up to a third of its physical strength. Other treated fish no doubt had moderate loss of physical stregth, none serious enough to effect survival unless placed under extreme stress.

Recovery from mild Seven intoxication by fish in the stream should be rapid. However, no data have been determined on recovery time from sublethal carbamate intoxication in fishes.

Conclusions

There should be little or no lasting effect of the Sevin spraying to rainbow trout held in the stream at Station #8.

The reduction of brain acetylcholinesterase activity and subsequent loss of physical strength by the fish may not have been noticeable to the observer.

Recovery from the minor reduction in tissue acetylcholinesterase activity in fish held in the stream during and after spraying of Sevin should be rapid and complete.

/s/ George Post, Ph. D.

Fish & Wildlife Consultant

APPENDIX I

Silvicultural Discussion

The western spruce budworm is an indigenous component of the Douglas-fir/true fir and mixed conifer forests of the Pacific Northwest. It is frequently found in a wide variety of forest and environmental conditions ranging from shade and ornamental trees in urban areas to forested areas. Its extensive occurrence is indicative of its broad tolerance to environmental conditions. Nevertheless, the budworm population, like all insects, is responsive to and limited by its environment. These are broad limits determined by a complex interaction of climate, site, host, predators, and the insect itself. This complexity becomes particularly important when considering manipulation of the insect's environment to regulate the insect's population levels. Add to this the vast host acreage encompassing millions of acres of commercial and noncommercial forest land, including public and private ownership, and the task of host manipulation as a method of budworm control can better be seen as a long-term forest management strategy.

The USDA Forest Service has long recognized the importance of forest management to minimize the damaging effects of forest insects and disease, especially in the forests east of the Cascade Mountains in Oregon and Washington. Over several decades, a combination of factors, including past cutting practices, fire exclusion, and management philosophy have brought about changes in the structure and composition of forests, resulting in an increase of Douglas-fir and true fir, particularly true fir (Hall 1981, West 1969). White fir and grand fir forest types are recognized as having some potentially serious insect and disease problems, including Douglas-fir tussock moth, western spruce budworm, root rots, and stem decay. However, on many sites in Eastern Oregon and Washington (white fir - twin flower - forb, and white fir - huckleberry sites), the true firs are not only the best adapted but will out-produce other species by at least 20 percent in terms of volume production (Hall, 1980 and 1981). As a result, while recognizing the increased hazard, forest management philosophy has often favored grand fir/white fir.

Over the past several years, however, recognition of the potential insect and disease problems, particularly of grand fir/white fir, has resulted in the development of the following general silvicultural prescriptions for use in considering long-term management:

a. Regenerate mature grand fir/white fir stands. High-hazard areas can be identified as composed primarily of true fir on ridge tops or steep slopes and/or having evidence of root rot pockets or severe stem decay.

(1) Strive for species diversity but favor the seral species, except where grand fir/white fir is seral and root rot or stem decay has been present.

(2) Avoid planting true fir. It will usually regenerate naturally but should not be allowed to exceed 30 percent of the stems per acre. Where root disease has been a problem, grand fir/white fir regeneration should be completely discriminated against.

b. Where partial cuts are necessary, favor seral species in the overstory.

(1) Select the least suppressed advanced true fir regeneration for future crop trees. If advanced regeneration with wounding is present, the site should be hazard-rated for Indian paint fungus.

c. Avoid sanitation/salvage operations, especially where root rots have been present.

d. Where stocking level control is necessary, always favor mixed species. Grand fir can be favored where it is seral (again, the exception is where root rot or stem decay has been present).

This fir and mixed conifer prescription is based upon a combination of the effects of tussock moth, budworm, and disease and focuses primarily on grand fir/white fir. For example, there is considerable information indicating the susceptibility of true fir, especially where it is climax, to pest problems. Stoszek and Mika (1978) developed a site/stand hazard rating for tussock moth which identified, among other factors, that stands comprised primarily of grand fir sustain more damage than do other stands. Williams (1967), Carolin and Coulter (1975), and Bousfield et al. (1975) have shown the greater susceptibility of true firs to budworm damage. Filip and Goheen (1985)

have reported on the potentially serious problems of white fir and grand fir in their susceptibility to root diseases such as *Phellinus weirii, Armillaria ostoyae,* and *Fomes annosus*. Aho (1977) found grand fir to be the most defective of the major commercial species comprising the associated species or mixed conifer types in the Blue Mountains of Oregon.

The Canadian/U.S. Spruce Budworm Program has supported studies related specifically to silvicultural management of budworm. Stoszek and Mika (1983) and Ulliman and Kessler (1983) have identified site and stand conditions related to budworm incidence. These include stand elevation, purity, average crown diameter, age, basal area, topographic position, aspect, and crown competition factors. These variables are combined in a mathematical model enabling a prediction of defoliation intensity for a given site. After initial testing, however, the model developed for use in Idaho has not been found to be generally applicable to eastern Oregon or Washington.

In the northern Rocky Mountains, Carlson et al. (1983) have found that dry Douglas-fir sites, particularly on steeper sites, are more vulnerable to budworm defoliation. This susceptibility of warm, dry habitat types has also been reported by Faus and Pierce (1969) and Stoszek and Mika (1983).

Kemp et al. (1983) have attributed outbreak frequency to lower January mean maximum temperatures, lower January mean minimum temperature, lower July mean minimum temperatures, and lower mean annual precipitation. This relationship between budworm outbreaks and weather has also been observed by Hard et al. (1980) and Twardus (1980).

The integration of these pest considerations into the long-term management of East-side National Forests has developed over the past several years. It has been a slow process, largely dependent upon information relating to pest impact and management consequences becoming available to forest managers. As the preceding literature citations have shown, much of this information has only recently become available. As pest management guidelines become available and are considered with forest management multiple-use goals and objectives, "state-of-the-art" prescriptions are being implemented on an individual stand basis. This is a long-term pest prevention solution, and it does little to alleviate the current outbreak. For as much as budworm outbreak dynamics are presently understood, the current outbreak is partially the result of several decades of forest management practices over millions of publicly and privately owned acres. From a National Forest standpoint, it will take at least that long to remedy. Even with the long-term adoption of a pest preventative management scheme, the problem would not quickly disappear.

The broad tolerance limits of the budworm population enables it to survive under varied conditions. Wherever there is Douglas-fir and true fir, particularly true fir, budworm-caused defoliation can be expected at some time. Douglas-fir and true fir will always be a component of these forests. They are commercially valuable species favored by the silvicultural practices of many industrial and nonindustrial private landowners, and are also an important component of the multiple-use objectives of National Forests (including old-growth reserves and other special designated areas). They are excellent species for intensive management, a factor which must be weighed against insect and disease problems. The key, however, is to minimize the total stand impact, not only from budworm, but from the entire pest complex of true fir. The true fir prescription, as outlined, is expected to achieve this goal where operationally and administratively possible. On some Forests, it will take an estimated 60 years to implement, but over that time, each stand treated results in that much less pest-susceptible acreage.

The use of silvicultural manipulation of forests to reduce and/or prevent western spruce budworm damage is a long-term solution and is not applicable to the current outbreak and its effects. It is an on-going process and one that will continue to be in effect regardless of decisions about future spray treatments which are made based upon this analysis.

APPENDIX J

Stream Classification

USDA Forest Service Classification:

Class I. Perennial or intermittent streams, or segments thereof, that have one or more of the following characteristics:

Direct source of water for domestic use (FSM 2543 - cities, recreation sites, etc.).

Used by large numbers of fish for spawning, rearing, or migration.

Flow enough water to be a major contributor to the quantity of water in a another Class I stream.

Class II. Perennial or intermittent streams or segments thereof, that have one or both of the following characteristics:

Used by moderate, though significant, numbers of fish for spawning, rearing or migration.

Flow enough water to be a moderate or not clearly identifiable contributor to the quantity of water in Class I streams, or be a major contributor to a Class II stream.

Class III. All other perennial streams, or segments thereof, not meeting higher class criteria.

Class IV. All other intermittent streams, or segments thereof, not meeting higher class criteria.

State of Oregon Classification:

Class I. This includes USFS Class I and Class II described above.

Class II. This includes USFS Class III and Class IV described above.

State of Washington Classification:

Type 1 Water. All waters within their ordinary high-water mark as inventoried as "shorelines of the State" under Chapter 90.58 RCW, but not including those waters' associated wetlands.

Type 2 Water. Segments of natural waters having a high use and of high importance from a water quality standpoint for: (1) domestic water supplies, (2) public recreation, (3) fish spawning, rearing or migration, or wildlife uses, or (4) highly significant protection of water quality - corresponds to USFS Class I stream.

Type 3 Water. Segments of natural waters not classified as Type 1 or Type 2 having moderate to slight uses as do Type 2 waters. Corresponds to USFS Class II Stream.

Type 4 Water. Segments of natural waters not classified as Type 1, 2, or 3. Significance lies in their influence on water quality downstream on higher classified waters. Roughly corresponds with USFS Class III Stream but can be intermittent.

Type 5 Water. Segments of natural waters with or without a natural channel not classified as Type 1, 2, 3, or 4. Includes natural sinks, springs, seeps and ephemeral streams associated with spring runoff. Roughly corresponds to USFS Class IV Stream.

[illegible]

[illegible] Oregon Climate [illegible]

[illegible]

[illegible] of Translation from [illegible]

[illegible]

APPENDIX K

Suppression Investments And Opportunities

1. Past management investments: Concern has been expressed that an economic analysis might not be sensitive to past management investments, and that benefits to be gained by these investments might be lost without special consideration.

Discussion: The economic analysis process that has been developed will recognize indirectly those past management investments which have an impact on tree growth. Timber stands with past investments are generally more intensively managed and faster growing than slower-growing, less productive, unmanaged natural stands. Because the managed stand has greater capacity for growth, it has greater potential for economic losses to forest pests. Therefore, further investment in a treatment to prevent budworm damage would avert substantially greater economic losses in the managed stand. Past management investment decisions are sunk costs; those decisions are irretrievable and not relevant to the decision at hand. The relevancy of past investments is reflected in a particular stand's growth capacity rather than in dollars that have already been spent.

2. Accomplishment of a western spruce budworm management program within current administrative constraints, which includes funding, personnel, travel, and related items:

Discussion: Implementation of the selected alternative(s) will be contingent upon landowners or land managers being able to commit the financial resources necessary to accomplish the selected course of action. If these resources are not available, implementation of the proposed alternative(s) may have to be delayed or foregone.

3. Control projects offer an opportunity to study the effects resulting from currently viable methods of integrated pest management and develop data on effects and use of promising alternative methods:

Discussion: The participating agencies recognize this opportunity to add to the present level of knowledge about currently accepted methods of pest management.

4. Reduced funding combined with anticipated high cost could reduce the effectiveness of control experienced with past projects, as well as increase the risk of poor application and accidents:

Discussion: It has been identified elsewhere in this appendix (see item 2) that implementation of any treatment project is dependent upon landowners and land managers being able to commit the necessary financial resources. Units will be treated to the extent of available funding, implementing all requirements listed in this Environmental Assessment (EA). Standards will not be sacrificed in order to treat a greater number of acres.

5. Reduced funding and constrained State budgets may require increases in private landowner share of costs or significantly limit the number of acres that can be adequately treated:

Discussion: This is a valid concern since reductions are expected in both Federal and State money for cost-sharing. Much of the burden of covering treatment costs on privately owned land may have to be placed on the landowner. Because funding appropriation is out of the Responsible Official's control, this concern is beyond the scope of this analysis and cannot be resolved herein.

6. There is some concern that improper or lax contracting procedures may permit contract awards to less than qualified firms, thereby increasing risk to the public and the environment:

Discussion: Federal regulations prohibit awarding contracts to unqualified firms.

7. Some people are concerned about the fairness-of- decision criteria in determining properties to be treated or not. Who receives benefits over those who do not?

Discussion: The decision to carry out treatments based upon this analysis is the responsibility of the respective land managers. Likewise, any private landowner has the option to treat his/her land if desired, regardless of the decisions made from this analysis. Analyzing opportunities for participation in Federal and/or State cost-sharing programs is not within the scope of this analysis.

8. With reduced possibilities for cost-sharing and the adoption of multiple treatment scenarios, there is concern that State agencies of Oregon and/or Washington would be unable to implement Infestation Control Districts requiring treatment to control the budworm:

Discussion: The designation of an Infestation Control District requiring a landowner to control a forest pest or be charged by the State to do the control, has little to do with the decision of the State to cost-share for that control. The need to consider multiple treatments rather than just one to control a pest should also have little effect on the requirement and need for control. If control of a pest requires more than one treatment in order to ensure maximum protection of a timber resource, the laws allowing for the designation of an Infestation Control District still apply. Procedures leading to implementation of these laws are beyond the scope of this analysis.

APPENDIX L

Accidents

During the 1983 budworm control project, five accidents occurred in the Pacific Northwest Region. Four involved spray helicopters, and the fifth involved a truck transporting insecticide to a helicopter batch site. One spill involving a helicopter occurred in 1985. No accidents occurred on either the Malheur or Rimrock projects in 1987. In 1988, a major helicopter accident on the Warm Springs Project resulted in the loss of life.

The potential for accidents exists whenever aircraft are used to apply pesticides. In general, there are three causes of accidents during a treatment project:

Mechanical Failure:

Accidents resulting from mechanical failure can be from loss of power needed to maintain flight, loss of maneuverability, and malfunction of the mechanisms controlling the application of the pesticide, including those involved with the emergency release system. Many mechanical-failure accidents can be prevented by rigorous maintenance and routine inspections.

The types of accidents caused by mechanical failure include: damage to the aircraft and injury or death to the pilot resulting from a forced landing, unintentional activation of the emergency release system causing unknown environmental effects, and unintentional application on nontarget areas due to faulty spray control.

Human Error:

Human error can be a major factor in the number and types of accidents that can occur during the aerial application of a pesticide. Three of the four aircraft accidents in 1983 and the spill in 1985 can be attributed to human error. The use of experienced and qualified pilots can help reduce the number of accidents caused by human error when treating a forested environment.

The types of accidents that can result from human error include: unintentional activation of the emergency release system, pilots' misjudgment causing loss of control while in-flight or during takeoff and landing, and unintentional application to nontarget areas.

Environmental Conditions:

Certain environmental conditions can result in an accident. These conditions are the least controllable. These types of accidents include: loss of control and damage to the aircraft, and creating the need for the pilot to activate the emergency release system and dumping the pesticide load.

Accidents involving pesticides can also occur during the transport and mixing of pesticides on the ground; as was the case in 1983 when a truck transporting insecticide to a helicopter batch site lost control, left the road and crashed, spilling approximately 1,900 gallons of formulated Sevin 4-Oil and diesel fuel into Willow Creek. As with aircraft, accidents on the ground can occur during a project for similar reasons: 1. Mechanical failures of equipment, 2. Human error, and 3. Environmental conditions.

There is a potential for accidents to occur on future insect suppression projects. However, much has been learned from accidents on previous projects and has been utilized in the development of standards, guidelines, and mitigation measures. The standards, guidelines, and mitigation measures developed for these alternatives were designed to prevent, reduce the probability, and lessen the impacts of similar future incidents.

APPENDIX M

Integrated Pest Management

The USDA Forest Service Pest Management Policy is built upon the concept of Integrated Pest Management (IPM). IPM is an ecologically based approach that includes the following types of activities: monitoring, prevention, suppression, and evaluation.

IPM prevention activities are part of land management objectives. The ecological principles relating to pests are incorporated into forest and range management evaluations, planning, and decisionmaking. IPM includes an intensive continuing program of detection and evaluation of pest situations, supplying information to planners and decisionmakers. The fundamental intent of prevention is to avoid creating ecological conditions that favor pests, to correct pest management-created conditions that foster further pest problems, or both.

Suppression, as related to IPM, involves evaluating the spectrum of possible suppression alternatives and, in each case, selecting an optimal strategy. That strategy may be a single tactic, concurrent measures, or a sequential combination of tactics. The evaluation considers the expected effectiveness of treatments in achieving resource management goals, as well as such factors as economics, environmental concerns, and human safety. Suppression takes two forms: direct and indirect. Direct suppression means taking action directly against a pest to reduce its population; for example spraying insecticides, using prescribed fire, removing pests contained in infested materials, or releasing parasites or predators. Indirect suppression is similar to prevention since it involves altering conditions that favor a pest population, thereby causing a decline in numbers. Indirect suppression methods are applied to damaging pest populations that already exist with the intent of limiting damage to tolerable levels.

Post suppression activities include monitoring and post treatment evaluations to determine the effectiveness and efficiency of suppression efforts. Effectiveness evaluations are ideally made in terms of net resource value changes rather than pest population numbers. To improve overall program performance, information gathered during the post suppression phase is fed back into the system, and appropriate adjustments are made.

A feature of IPM is the consideration of other potential pest problems when making individual situation analyses. The goal is to avoid creating or intensifying one pest problem while attempting to alleviate another. The strength of the IPM philosophy is requiring that the three phases of pest management be incorporated into the broad arena of forest and range management. IPM is found in the planning, decisionmaking, and program implementation functions.

APPENDIX N

Treatment History 1982-1988

In the 1982 Budworm Suppression Project, budworm populations were below the target level of 7 larvae/100 buds in carbaryl-treated areas 14 days after treatment. Posttreatment populations, averaging 9.1 larvae/100 buds in acephate-treated areas, did not meet the targeted level (Hostetler, 1983). Since acephate is a water-soluble formulation, rain showers within 1 day after treatment may have removed some of the toxicant from the target foliage in some areas. In other areas, where rain was not a factor, other conditions affecting the quality of spray application may have been responsible for the undesirable results.

Defoliation sampling was conducted within 1982 treatment units at many of the larval population sampling sites during 1983. In the carbaryl-treated units, the overall defoliation was light in one unit, light to moderate in two, and moderate in one. Defoliation in the acephate-treated unit was heavy. An untreated unit showed extremely heavy defoliation.

In the approximately 525,000 acres treated with carbaryl during 1983, larval sampling 2 to 3 weeks after insecticide application indicated budworm populations were reduced to below targeted levels of 1.5 larvae per 45-cm branch tip on about 80 percent of the units treated (Bridgwater, 1983). The 1.5-larvae-per-branch-tip target equates to about 4.5 larvae per 100 buds--the unit of measure used in 1982. On the other 20 percent of the treatment units, while population levels were greatly reduced, they remained above targeted levels, ranging from 1.7 to 3.3 larvae per 45-cm branch tip. These higher levels may have been due to problems with application rather than insecticide ineffectiveness.

The 1987 suppression projects had mixed results. Of the three units treated with *B.t.* (North and South Units on the Malheur National Forest and Rimrock on the Wenatchee National Forest), the Rimrock Unit was an unqualified success. On the Rimrock Unit, all contracted acreage (44,000) was treated, the population density was reduced to 0.89 ± 0.10 budworms per 45-cm branch tip, and spray deposit was acceptable. There were no application, administrative, or contractual problems of note.

The North and South Units on the Malheur National Forest will be discussed as one. Because of administrative and contractual problems, only 94,000 of the 204,000 acres originally contracted for were treated. Of those acres treated, 34,500 had budworm population densities reduced to 1.11 ± 0.19 budworms per 45-cm branch tip; barely meeting the threshold value of 1 larva per branch tip. Spray deposit was judged as marginally acceptable on those acres. The rest was considered as unacceptable. This unacceptable spray deposit was determined to be caused by poor formulation of the product.

Small areas on the Ochoco and Malheur National Forests were treated with *B.t.* in 1984 and 1985 to determine the cost-effectiveness of various formulations and application techniques. The 1984 test confirmed that 12 billion international units (BIU's) per acre is superior to 8 BIU's per acre, and that application with small helicopters using rotary atomizer spray nozzles which produce relatively small droplets (i.e., mass median diameters of 100 to 125 microns) is desirable. Population reduction to below 1.5 larvae per 45-cm branch tip was reached on about 75 percent of the treated plots (Beckwith, Stelzer, and Hostetler, 1984). In 1985, an operational evaluation on the Malheur National Forest was conducted to determine if *B.t.* could reduce budworm populations to or below 1 larva or pupae per 45-cm branch tip. The evaluation was unable to discern significant differences among any of the treatments, all of which were successful. A helicopter application of Thuricide 32LV, 16 BIU's per acre, applied at 64 fl. oz. per acre, resulted in the lowest density of surviving larvae and pupae. This reduced survivors to 0.37 per 45-cm branch tip (Ragenovich, 1986).

In 1988, a major set of suppression and developmental projects was conducted in Oregon to deal with the current outbreak. As in 1987, the threshold for a successful posttreatment population reduction was less than 1 larva/45-cm branch tip. This level is used since, as determined in the 1985 special evaluation, it is achievable when good applications are made. The level is not only related to the insecticide used, but also to the quality of the application and the administration of the project. Biologically, it is also desirable to reduce the budworm populations to nearly

undetectable, endemic, levels so normal processes will again exert control.

Operational units on the Mt. Hood National Forest had the following posttreatment results: Dalles, 2.40±.36 larvae/45-cm branch tip on an area of 116,000 acres; Barlow, 0.56±.07 larvae/tip on an area of 140,000 acres; and Warm Springs, 0.57±.08 larvae/tip on an area of 186,000 acres. The Dalles units did not meet the predetermined threshold for acceptable posttreatment population densities. This may have been due to poor application within portions of the unit. In addition, there were very high populations of budworm in portions of the unit.

Units on the Tollgate project on the Umatilla National Forest had the following posttreatment results: 0.55±.09 and 0.68±.14 larvae/45-cm branch tip over approximately 107,000 acres, and 1.42±.38 larvae/tip over approximately 2,000 acres. The unit not meeting the threshold of 1 larva/tip was thought to have received a poor treatment.

Projects conducted by Longview Fiber Company and Hood River County used both carbaryl and *B.t.* Over an area of 33,000 acres, carbaryl reduced populations to an average of 0.49 larvae/45-cm branch tip. *B.t.* gave variable results over 6,700 acres resulting in an average of 2.32 larvae/tip. Results may differ due to variations in spray deposit. The average deposit on carbaryl spray deposit cards was 25 drops/square centimeter, whereas the *B.t.* averaged 14 drops.

The Boise Cascade Corporation conducted a small-scale project near Elgin, Oregon, using carbaryl. Rumors are that results were excellent.

In a pilot project conducted near Meacham, Oregon, to determine the feasibility of using undiluted formulations of *B.t.* at 43 oz.(16 BIU)/acre, the following posttreatment results were obtained: Dipel 6AF, 2.17 larvae/45-cm branch tip, 87.8 percent population reduction; Thuricide 48LV, 1.03 larvae/tip, 94.7 percent population reduction; and the control 7.83 larvae/tip, 54.7 percent population reduction. These are preliminary results, however it appears only Thuricide 48LV was close to meeting the criteria of reducing the population to less than 1 larva per tip.

A special project was conducted in the Mt. Hood National Forest to determine the handling and application characteristics of two formulations of *B.t.*, Dipel 6L applied undiluted at 43 oz. (16BIU)/acre, and Thuricide 32LV applied undiluted at 64 oz.(16BIU)/acre respectively. Preliminary results indicate both formulations reduced populations of budworm to below the 1 larva/45-cm branch tip threshold. Thuricide 32LV reduced populations to 0.28±.08 larvae/tip, 94.0 percent population reduction. Dipel 6L reduced populations to 0.90 larvae/tip, 90.4 percent population reduction.

From the preceeding it is apparent that under the conditions of these projects there is no practical difference in the short-term population reduction efficacy of carbaryl or *B.t.*; both can reduce populations to less than 1 larva/45-cm branch tip given proper application and project administration. There are, however, potential differences which may make one more desirable than the other in affecting long-term suppression of budworm populations.

An insecticide with both contact and stomach toxicity modes of action provides more flexibility in timing applications. For instance, volatile portions of a contact insecticide can kill early instar budworm larvae that are protected by webbing from ingesting stomach poisons. If not killed, some become so agitated that they drop from foliage and are lost from the defoliating population or become easier prey for natural enemies. Also, if applications are delayed, a contact insecticide can kill late instar larvae that have already stopped feeding and wouldn't be susceptible to a stomach poison. An insecticide with both contact and stomach poison attributes, theoretically, could have a wider window of application. Carbaryl has both contact and stomach poison modes of action, while *B.t.* has only the stomach poison mode of action.

The residual activity of an insecticide formulation on the target surface, in this case, tree foliage, determines in part how useful it is. Foliage residues of 2.74 parts per million were found after spraying with 0.5 lb. carbaryl/acre for spruce budworm control in Minnesota. These declined to 1.14 ppm after 10 days (Millers, 1976). When 1.0 lb. carbaryl per acre was applied in Maine for spruce budworm control, immediate postspray foliage residues of 1.99 ppm were observed. Residues of 1.12 ppm were found after 14 days, and after 28 days, no detectable residues (0.02 ppm) remained (LOTEL, 1977). Carbaryl is thought to have approximately a 10- to 14-day half-life, or practical insecticidal life, on host tree foliage in the Northwest. Early work on formulations of *B.t.* showed that most insecticidal activity had disappeared after 3-4 days (Beegle et al., 1981; Ignoffo et al., 1974). A study on two contemporary formulations of *B.t.* in the forested environment (Beckwith and Stelzer, 1987) suggests that degradation is not that rapid. The time to 50 percent original activity for both strains exceeded the 10-day sample. Values of 13.9 and 44.2 days for 30 BIU/ha were calculated for SAN-415 and Thuricide 32LV, respectively. From this information, it is inferred that contemporary *B.t.* formulations have at least a 14-day practical insecticidal life on host tree foliage in the Northwest.

B.t. has the potential for longer activity in the target budworm population and in following generations (Klein and Lewis, 1966; Morris, 1977; Smirnoff, 1979). Some of the variation in budworm control noted in past studies could be related to the slower action of the bacteria in causing insect mortality; that is, some mortality may have occurred after measurements were made. Stipe et al. (1983) indicate some carry-over effect after the first year of treatment. The effects, while observed, have not been explained. Larvae that are parasitized are usually more sluggish and do not feed as much as larvae that are free of parasites (Lewis, 1960; Leonard and Simmons, 1974; Hamel, 1977). This results in their being in the larval stage longer and more apt to be found by predators.

The above information suggests there may be little difference in persistence of practical insecticidal residues between carbaryl and *B.t.* formulations. The beneficial effects of *B.t.* applications may be carried over to subsequent years, however, no research has been conducted to fully document or explain their occurrence.

The mode of action of an insecticide and its residual characteristics has effects not only on the target organism, budworm, but also on nontarget organisms. Some nontarget organisms are beneficial natural enemies of budworm. While not thought to be significant factors in reducing outbreak populations, they are known to be significant mortality factors in endemic populations. If these populations are damaged during suppression projects, they may be unable to exert their natural controls when a suppression project has driven the budworm population to endemic status. Without these controls, the population may rebound to epidemic levels. Carbaryl is a broad-spectrum insecticide having both contact and stomach toxicity modes of action, as well as relatively long persistence on forest tree foliage.

In 1983, during a budworm suppression project using 1 lb. carbaryl/acre, Murphy (personal communication) examined possible effects on the foraging activity of predaceous ants. Foraging activity was reduced for at least 6 weeks, effectively negating their activity for that generation of budworm. Two species were not found in the spray areas, whereas they remained in the untreated control areas and increased in density. No work was done after the sampling 6 weeks after spraying.

Carbaryl may have a slight direct toxic effect on some bird predators, plus an indirect effect in reducing budworm and other insect prey species. *B.t.* has only insecticidal effects on certain lepidopterous species that are feeding on the sprayed foliage when the residues are at insecticidal levels.

APPENDIX O

List of Agencies, Organizations, and Persons to Whom Copies of the Environmental Impact Statement Were Sent.

These are the agencies, organizations, and individuals who were listed to receive this EIS as of early September 1988. Since then, others have been listed and will receive copies.

Federal Agencies and Officials

U.S. Department of Agriculture:

Agricultural Stabilization and Conservation Service, Washington, DC

Animal and Plant Health Inspection Service, Washington, DC

Office of Equal Opportunity, Washington, DC

Rural Electrification Administration, Washington, DC

Soil Conservation Service, Washington, DC

USDA Forest Service, Washington DC

Forest Service Regional Offices

- Alaska Region, Juneau AK
- Eastern Region, Milwaukee, WI
- Intermountain Region, Ogden, UT
- Pacific Southwest Region, San Francisco, CA
- Rocky Mountain Region, Lakewood, CO
- Southern Region, Atlanta, GA
- Southwestern Region, Albuquerque, NM
- Northern Region, Missoula, MT

National Forests

- Colville
- Deschutes
- Fremont
- Gifford Pinchot
- Malheur
- Mt. Baker-Snoqualmie
- Mt. Hood
- Ochoco
- Okanogan
- Olympic
- Rogue River
- Siskiyou
- Siuslaw
- Umatilla
- Umpqua
- Wallowa-Whitman
- Wenatchee
- Willamette
- Winema

Experiment Stations

- Pacific Northwest
- Rocky Mountain
- WESTFORNET-North, Seattle, WA
- WESTFORNET-South, Berkeley, CA

Architectural and Land Environmental Preservation, Washington, DC
Centers for Disease Control, Alanta, GA

Commerce, Department of

- National Marine Fisheries Service:
- Southwest Division, Terminal Island, CA
- Northwest Division, Portland, OR
- NOAA Ecology/Conservation Division

Defense, Department of

- Army Corps of Engineers, Washington, DC
- Army Corps of Engineers, Portland, OR
- Army Corps of Engineers, Seattle, WA
- Deputy Assistant Secretary of Defense, Washington, DC
- US Air Force, Environment and Safety, Washington, DC
- US Navy, Environment Protection Division, Washington, DC
- Naval Oceanography Division, Naval Observatory, Washington, DC

Energy, Department of

- Bonneville Power Administration, Portland, OR
- Office of Environmental Compliance, Washington, DC
- Richland Operation Office, Richland, WA

Environmental Protection Agency

- Region IX, San Francisco, CA
- Region X, Seattle, WA

Federal Energy Regulatory Commission

- Office of Environmental Review, Washington, DC

Federal Highway Administration

- Region 10, Portland, OR
- Region 9, San Francisco, CA

Federal Railroad Administration, Washington, DC
General Services Administration, Environmental Staff, Washington, DC
Health and Human Services, Washington, DC
Housing and Urban Development, Office of Environment and Review, Washington, DC
Housing and Urban Development, Region 1X

Interior, Department of

- Bureau of Land Management, Portland, OR
- Bureau of Indian Affairs, Portland, OR
- Fish and Wildlife Service, Portland, O
- Interstate Commerce Commission, Washington, DC

National Aeronautics and Space Administration, Washington, DC
National Endowment for the Arts, Washington, DC

Nuclear Regulatory Commission

- Environmental Projects Office, Washington, DC
- Occupational Safety and Health Administration, Washington, DC

Transportation, Department of

- Environmental Division, Washington, DC
- Federal Aviation Administration, Northwest Region, Seattle, WA
- Federal Aviation Administration, Western Region, Los Angeles, CA

Canada

- Canadian Ministry of Environment and Parks, Victoria, BC

Federal Congressional Delegation

Oregon

- Senator Mark Hatfield
- Senator Bob Packwood
- Representative Peter Defazio

Representative Denny Smith
Representative Ron Wyden
Representative Les Aucoin

Washington

Senator Brock Adams
Senator Dan Evans
Representative Rod Chandler
Representative Norman Dicks
Representative Thomas Foley
Representative Mike Lowry
Representative Don Bonker
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Industry and Organizations

Native Plant Society of Oregon
Soil Remineralization
Center Evironmental Health and Injury Control
Mt. Hood Forest Study Group
Our National Forest, Inc.
Washington Forest Protection Association
Lava Nursery, Inc.
Lane County Audubon Society
Mountain Fir Lumber Co. Inc.
Northwest Forestry Association
Washington Farm Forestry Association
Jepsen Pest Control, Inc.
Northwest Independent Forest Manufacture
Dow Chemical Company
Canadian Earthcare Society
Associated Oregon Loggers, Inc.
Boise Cascade Corporation
Mason County PUD #1
Weyerhaeuser Company
Douglas Timber Operators, Inc.
Oregon Council, Trout Unlimited

- Tilth Producers Cooperative
- Simpson Timber Company
- Jollis, Sokol & Berstein, PC
- Half-Baked Enterprises
- Washington Friends of Farms & Forests
- D.R. Johnson Lumber Company

State and County Agencies

- County Noxious Weed Control Board, Clackamas County, OR
- California State Conservationist, Davis, CA
- Washington State Conservationist, Spokane, WA
- Washington State Forest Practices Board
- Washington State Department of Fisheries
- Washington State Department of Wildlife
- Hood River County Forestry Department
- County Weed District No. 1, Grant County WA
- Oregon Department of Fish and Wildlife
- Oregon State Department of Forestry.
- Oregon State Conservationist, Portland, OR

University Libraries

- Willamette Institute of Biological Control
- Central Oregon Community College
- Oregon State University
- Blue Mountain Community College

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APPENDIX P

Results of Suppression Projects During the Current Outbreak

In the 1982 Budworm Suppression Project, budworm populations were below the target level of 7 larvae/100 buds in carbaryl-treated areas 14 days after treatment. Post-treatment populations averaging 9.1 larvae/100 buds in acephate-treated areas did not meet the targeted level (Hostetler, 1983). Since acephate is a water-soluble formulation, rain showers within 1 day after treatment may have removed some of the toxicant from the target foliage in some areas. In other areas, where rain was not a factor, other conditions affecting the quality of spray application may have been responsible for the undesirable results.

Defoliation sampling within 1982 treatment units at many of the larval population sampling sites was conducted during 1983. In the carbaryl-treated units, the overall defoliation was light in one unit, light to moderate in two, and moderate in one. Defoliation in the acephate-treated unit was heavy. An untreated unit showed extremely heavy defoliation.

In the approximately 525,000 acres treated with carbaryl during 1983, larval sampling 2 to 3 weeks after insecticide application indicated that budworm populations were reduced to below targeted levels of 1.5 larvae per 45-cm branch tip on about 80 percent of the units treated (Bridgwater, 1983). The 1.5-larvae-per-branch-tip target equates to about 4.5 larvae per 100 buds--the unit of measure used in 1982. On the other 20 percent of the treatment units, population levels were greatly reduced, but remained above targeted levels, ranging from 1.7 to 3.3 larvae per 45-cm branch tip. These higher levels may have been due to problems with application rather than insecticide ineffectiveness.

The 1987 suppression projects had mixed results. Of the three units treated with *B.t.* (North and South Units on the Malheur National Forest and Rimrock on the Wenatchee National Forest), the Rimrock Unit was an unqualified success. On the Rimrock Unit, all contracted acreage (44,000) was treated, the population density was reduced to 0.89 ± 0.10 budworms per 45-cm branch tip, and spray deposit was acceptable. There were no application, administrative, or contractual problems of note.

The North and South Units on the Malheur National Forest will be discussed as one. Because of administrative and contractual problems, only 94,000 of the 204,000 acres originally contracted for were treated. Of those acres treated, 34,500 had budworm population densities reduced to 1.11 ± 0.19 budworms per 45-cm branch tip; barely meeting the threshold value of 1 larva per branch tip. Spray deposit was judged as marginally acceptable on those acres. The rest was considered as unacceptable. This unacceptable spray deposit was determined to be caused by poor formulation of the product.

Small areas on the Ochoco and Malheur National Forests were treated with *B.t.* in 1984 and 1985 to determine the cost-effectiveness of various formulations and application techniques. The 1984 test confirmed that 12 billion international units (BIU's) per acre are superior to 8 BIU's per acre, and that application with small helicopters, using rotary atomizer spray nozzles which produce relatively small droplets (i.e., mass median diameters of 100 to 125 microns), is desirable. Population reduction to below 1.5 larvae per 45-cm branch tip was reached on about 75 percent of the treated plots (Beckwith, Stelzer, and Hostetler, 1984). In 1985, an operational evaluation was conducted on the Malheur National Forest to determine if *B.t.* could reduce budworm populations to or below 1 larva or pupa per 45-cm branch tip. The evaluation was unable to discern significant differences among any of the treatments, all of which were successful. A helicopter application of Thuricide 32LV, 16 BIU's per acre, applied at 64 fl oz per acre, resulted in the lowest density of surviving larvae and pupae. This reduced survivors to 0.37 per 45-cm branch tip (Ragenovich, 1986).

In 1988, a major set of suppression and developmental projects was conducted in Oregon to deal with the current outbreak. As in 1987, the threshold for a successful post-treatment population reduction was less than 1 larva/45-cm branch tip. This level is used since as determined in the 1985 special evaluation, it is achievable when good applications are made. The level is not only related to the insecticide used but also

to the quality of the application and the administration of the project. Biologically it is also desirable to reduce budworm populations to nearly undetectable, endemic, levels so normal processes will again exert control.

Operational units on the Mt. Hood National Forest had the following post-treatment results: Dalles, 2.40±.36 larvae/45-cm branch tip on an area of 116,000 acres; Barlow, 0.56±.07 larvae tip on an area of 140,000 acres; and Warm Springs, 0.57±.08 larvae/tip on an area of 186,000 acres. The Dalles units did not meet the predetermined threshold for acceptable post-treatment population densities. This may have been due to poor application within portions of the unit. In addition, there were very high populations of budworm in portions of the unit.

Units on the Tollgate project on the Umatilla National Forest had the following post-treatment results: 0.55±.09 and 0.68±.14 larvae/45-cm branch tip over approximately 107,000 acres, and 1.42±.38 larvae/tip over approximately 2,000 acres. The unit not meeting the threshold of 1 larva/tip was thought to have received a poor treatment.

Projects conducted by Longview Fiber Company and Hood River County used both carbaryl and *B.t.* Over an area of 33,000 acres, carbaryl reduced populations to an average of 0.49 larvae/45-cm branch tip. *B.t.* gave variable results over 6700 acres resulting in an average of 2.32 larvae/tip. The difference in results may be due to differences in spray deposit achieved. The average deposit on carbaryl spray deposit cards was 25 drops/sq cm, whereas *B.t.* averaged 14 drops.

The Boise Cascade Corporation conducted a small-scale project near Elgin, Oregon using carbaryl. Rumors are that results were excellent.

In a pilot project conducted near Meacham, Oregon, to determine the feasibility of using undiluted formulations of *B.t.* at 43 oz.(16 BIU)/acre, the following post-treatment results were obtained: Dipel 6AF, 2.17 larvae/45-cm branch tip, 87.8 percent population reduction; Thuricide 48LV, 1.03 larvae/tip, 94.7 percent population reduction; and the control 7.83 larvae/tip, 54.7 percent population reduction. These are preliminary results, however it appears that only the Thuricide 48LV was close to meeting the criteria of reducing the population to less than 1 larvae per tip.

A special project was conducted on the Mt. Hood National Forest to determine the handling and application characteristics of two formulations of *B.t.*, Dipel 6L applied undiluted at 43 oz. (16 BIU)/acre, and Thuricide 32LV applied undiluted at 64 oz.(16 BIU)/acre respectively. Preliminary results indicate that both formulations reduced populations of budworm to below the 1 larvae/45-cm branch tip threshold. Thuricide 32LV reduced populations to 0.28±.08 larvae/tip, 94.0 percent population reduction. Dipel 6L reduced populations to 0.90 larvae/tip, 90.4 percent population reduction. There were substantial differences in handling and application characteristics which will be discussed in the final report.

From the preceeding it is apparent that under the conditions of these projects there is no practical difference in the short-term population reduction efficacy of carbaryl or *B.t.*; both can reduce populations to less than 1 larvae/45-cm branch tip given proper application and project administration. There are, however, potential differences which may make one more desirable than the other in affecting long-term suppression of budworm populations.

An insecticide with both contact and stomach toxicity modes of action provides more flexibility in timing applications. For instance, volatile portions of a contact insecticide can kill early instar budworm larvae that are protected by webbing from ingesting stomach poisons. If not killed, some become so agitated that they drop from foliage and are lost from the defoliating population or become easier prey for natural enemies. Also, if applications are delayed, a contact insecticide can kill late instar larvae that have already stopped feeding and wouldn't be susceptible to a stomach poison. An insecticide with both contact and stomach poison attributes, theoretically, could have a wider window of application. Carbaryl has both contact and stomach poison modes of action, while *B.t.* has only the stomach poison mode of action.

The residual activity of an insecticide formulation on the target surface, in this case, tree foliage, determines in part how useful it is. Foliage residues of 2.74 ppm were found after spraying with 0.5 lb. carbaryl/acre for spruce budworm control in Minnesota. These declined to 1.14 ppm after 10 days (Millers, 1976 [Millers, E. 1976. Evaluation of 1 lb and 1/2 lb Sevin-4-Oil applications for spruce budworm control in Minnesota, 1975. USDA Forest Service, Northeast Area, State and Private Forestry, Forest Insect Disease Management, Upper Darby, PA, Evaluation Report S-23-76. 12 p.]). When 1.0 lb carbaryl per acre was applied in Maine for spruce budworm control, immediate post-spray foliage residues of 1.99 ppm were observed. Residues of 1.12 ppm were found after 14 days, and after 28 days, no detectable residues (0.02 ppm) remained (LOTEL, 1977 [Lake Ontario Environmental Laboratory (LOTEL). 1977. The environmental impact of Sevin-4-Oil (carbaryl) on a forest and aquatic ecosystem. SUNY Lake Ontario Environmental Laboratory, Oswego. LOTEL Report 215. 128 p.]). Carbaryl is thought to have

approximately a 10- to 14-day half-life or practical insecticidal life on host tree foliage in the Northwest. Early work on formulations of *B.t.* showed that most insecticidal activity had disappeared after 3-4 days (Beegle et al., 1981 [Beegle, C. C., H. T. Dulmage, D. A. Wolfenbarger, and E. Martinez, 1981. Persistence of *Bacillus thuringiensis* Berliner insecticidal activity on cotton foliage. Environ. Entomol. 10: 400-401.], Ignoffo et al. 1974 [Ignoffo, C. M., D. L. Hostetter, and R. E. Pinnell, 1974. Stability of *Bacillus thuringiensis* and *Baculovirus heliothis* on soybean foliage. Environ. Entomol. 3: 117-119.]). A study on two contemporary formulations of *B.t.* in the forested environment (Beckwith and Stelzer, 1987 [Beckwith, R. C. and M. J. Stelzer, 1977. Persistence of *Bacillus thuringiensis* in two formulations applied by helicopter against the western spruce budworm (Lepidoptera: Tortricidae) in North-Central Oregon. J. Econ. Entomol. 80: 204-207.]) suggests that degradation is not that rapid. The time to 50 percent original activity for both strains exceeded the 10-day sample. Values of 13.9 and 44.2 days for 30 BIU/ha were calculated for SAN-415 and Thuricide 32LV, respectively. From this information we infer that contemporary *B.t.* formulations have at least a 14-day practical insecticidal life on host tree foliage in the Northwest. *B.t.* has the potential for longer activity in the target budworm population and in following generations (Klein and Lewis, 1966; Morris, 1977; Smirnoff, 1979). Some of the variation in budworm control noted in past studies could be related to the slower action of the bacteria in causing insect mortality (Some mortality may have occurred after measurements were made). Stipe et al., (1983) indicate some carry-over effect after the first year of treatment. The effects, while observed, have not been explained. Larvae that are parasitized are usually more sluggish and do not feed as much as larvae that are free of parasites (Lewis, 1960; Leonard and Simmons, 1974; Hamel, 1977). This results in their being in the larval stage longer and more apt to be found by predators.

The above information suggests there may be little difference in persistence of practical insecticidal residues between carbaryl and *B.t.* formulations. The beneficial effects of *B.t.* applications may be carried over to subsequent years, however, no research has been conducted to fully document or explain their occurrence.

The mode of action of an insecticide and it's residual characteristics have effects not only on the target organism, budworm, but also on nontarget organisms. Some of these nontarget organisms are beneficial natural enemies of budworm. While they are not thought to be significant factors in reducing outbreak populations, they are known to be significant mortality factors in endemic populations. If these populations are damaged during suppression projects, they may be unable to exert their natural controls when a suppression project has driven the budworm population to endemic status. Without these controls, the population may rebound to epidemic levels. Carbaryl is a broad-spectrum insecticide having both contact and stomach toxicity modes of action as well as relatively long persistence on forest tree foliage.

In 1983, during a budworm suppression project using 1 lb carbaryl/acre Murphy (personal communication [Murphy, C. F., Department of Entomology, Oregon State University, Corvallis, OR 97331]) examined possible effects on the foraging activity of predaceous ants. Foraging activity was reduced for at least 6 weeks, effectively negating their activity for that generation of budworm. Two species were not found in the spray areas, whereas they remained in the untreated control areas and increased in density. No work was done after the sampling 6 weeks after spraying.

Carbaryl may have a slight direct toxic effect on some bird predators, plus an indirect effect in reducing budworm and other insect prey species. *B.t.* has only insecticidal effects on certain lepidopterous species that are feeding on the sprayed foliage when the residues are at insecticidal levels.

APPENDIX Q

Impacts Of Spruce Budworm Control Methods On Wildlife And Aquatic Species

Introduction

This section presents the results of the risk assessment conducted to evaluate the potential effects on terrestrial wildlife and aquatic organisms of carbaryl, the petroleum distillates diesel oil and kerosene, and *Bacillus thuringiensis (B.t.)* As in the human health risk assessment, the ecological effects assessment consists of hazard, exposure, and risk analysis components. Full details of the toxicity studies and methods for exposure calculations are given in Appendix X.

The potential impacts on wildlife and aquatic organisms of chemicals used in spruce budworm control may be direct or indirect. The chemicals may kill or seriously harm wildlife because of their inherent toxicity or they may indirectly affect wildlife by affecting their insect food supply. Based on the results of the exposure and hazard analyses, direct effects to wildlife populations should not be significant, although a number of individual animals may be killed as a result of a spraying or may receive a dose high enough to produce behavioral changes that could make them more vulnerable to predation or less successful in rearing offspring. Carbaryl does pose some risk of these direct effects. Diesel oil and kerosene, used as carriers, should not pose a significant risk to wildlife, although they may reduce egg production and hatchability in avian species. *B.t.* should not affect wildlife directly through toxicity.

Operational procedures call for a buffer zone between treated areas and bodies of water (except for small bodies of water and ponds). Thus, under normal operating conditions, the chemicals would reach major bodies of water only through spray drift. There should be no long-term effects to any species of aquatic organisms from using carbaryl in spruce budworm control operations. There is, however, a slight risk from the petroleum distillates under typical conditions, and a significant risk of adverse effects from petroleum distillates under worst case conditions.

Overview of the Ecological Risk Assessment

Hazard Analysis

The ecological hazard analysis evaluated the toxic properties of carbaryl, the petroleum distillates diesel oil and kerosene, and *B.t.* by summarizing the findings of laboratory and field studies. In some cases, laboratory studies of domestic animals have been used because of a lack of studies specifically on wildlife. The results of domestic animal studies are considered to be representative of the effects that would occur in the wild.

Exposure Analysis

The exposure analysis calculated exposures for a group of wildlife species representative of those typically found in areas supporting forest vegetation in the Pacific Northwest, representing a range of phylogenetic classes, body sizes, and diets. Representative species typical of aquatic habitats in the U.S. Forest Service Region 6 were used to estimate risk to aquatic organisms. Tables W-1 and W-2 list the wildlife and aquatic representative species.

Risk Analysis

Wildlife Risk Analysis. Wildlife species risk from spruce budworm suppression with insecticides is a function of the inherent toxicity (hazard) of each insecticide to different organisms and of the amount of each chemical (exposure) those organisms may take in as a result of a spraying operation. The wildlife species risk analysis compares estimated acute exposures of representative species determined in the previous section with acute toxicity levels found in laboratory studies.

For wildlife risks, the criteria used by EPA in ecological risk assessment (EPA, 1986c) were used to judge the absolute risks to the different representative species and the relative risks among the five

chemicals. The EPA criteria call for comparison of an estimated environmental concentration (EEC) with a laboratory-determined LD_{50} (median lethal dose) or LC_{50} (median lethal concentration) for the most closely related laboratory test species.

If the EEC exceeds 1/5 LD_{50} or 1/5 LC_{50}, EPA deems it a significant risk that may be mitigated by restricting use of the pesticide. EPA judges EEC's that exceed the LD_{50} or LC_{50} as unacceptable risk levels. Doses below the 1/5 LD_{50} level are assumed to present a low risk. In this risk assessment, an organism's total estimated dose (rather than an EEC) is compared with the laboratory toxicity level because the dose comes from all exposure routes, not just feeding.

The analysis of chemical risk to wildlife compared estimated acute doses for the representative wildlife species with available hazard information on the most closely related species. Because the chemicals examined show no tendency to bioaccumulate, long-term persistence in food chains and subsequent toxic effects, such as those that have resulted from the use of the persistent organochlorides, are not considered a problem and are not examined in the risk analysis. No analysis of chronic wildlife dosing was done because the chemicals degrade relatively rapidly and sites are normally treated only once per year.

Aquatic Risk Analysis. The risks of adverse effects from exposure to the insecticides that drift offsite and from accidents were estimated for the representative aquatic species described previously. Acute toxicity reference values (LC_{50}'s or EC_{50}'s - median effective concentrations) used in the analysis were selected for the representative species from relevant studies.

In cases where no acute toxicity reference value was available for a representative species, the value of the most closely related species was used. For fish species, preference was given to toxicity values of other species within the same genus or family. If no toxicity values were available for any member of that family, then the lowest value reported for any fish species was used.

To estimate the risk of adverse effects, the selected toxicity reference values were compared to the typical and worst case estimated environmental concentrations of each insecticide for a body of water 0.61 meter (2-feet) deep. The ratio of the EC to the LC_{50} (or EC_{50}) is called the quotient value (Q-value). Typical EEC's were based on typical application rates and a distance of 153 meters (500 feet) from the application site to the body of water. Worst case EEC's were calculated using maximum application rates and a distance of 30.5 meters (100 feet) to a body of water. EEC's for petroleum distillates were based on the fraction of kerosene in carbaryl formulations and the amount of diesel oil used as a carrier. The Q-values were compared to the risk criteria proposed by EPA (1986a) where the risks of adverse effects to fish or invertebrates are estimated as follows:

Q-value	Risk
EEC/LC_{50} < 0.1	No acute risk
EEC/LC_{50} $\geq$ 0.1 and <0.5	Presumption of risk that may be mitigated
EEC/LC_{50} $\geq$ 0.5	Presumption of significant risk of acute effects
EEC (NOEL or MATC[a]) <1.0	No chronic risk

Hazard Analysis

Wildlife Hazards

Carbaryl. Carbaryl is moderately toxic to mammals and slightly toxic to birds. The acute oral LD_{50} ranges from 150 mg/kg to 710 mg/kg for mammals, and from 780 mg/kg to more than 2,500 mg/kg for avian species (Ghassemi et al., 1981; Hudson et al., 1984; NLM, 1986b). These levels are not likely to be reached in a spruce budworm control spraying with carbaryl at 0.5 lb a.i./acre, the proposed rate for this program.

In Canada, no changes were observed in small mammal populations 2 months after spraying forested areas with carbaryl for spruce budworm control (Buckner et al., 1973). A study of an area in New York treated with 1.25 lb a.i./acre of carbaryl reported no adverse effects on small mammals or deer (Connor, 1960). At higher application rates (2 lb/acre and 4.46 lb/acre), decreases were seen in populations of moles and rodents (Denisova, 1973). These rates are 2-1/2 to 4 times higher than the 0.5 lb a.i./acre prescribed for spruce budworm treatment.

Several studies have shown no adverse effects on birds at application rates over twice that of the rate proposed for spruce budworm control (Connor, 1960; Zinkl et al., 1977; Richmond et al., 1979; McEwen et al., 1962; Bart, 1979; Buckner et al., 1973). Decreased levels of brain cholinesterase (ChE) were found in forest birds after applications of carbaryl at 1 lb a.i./acre, which may reduce a bird's ability to avoid predators and obtain food (Zinkl et al., 1977). Gramlich (1979) reported no ChE depression in birds

following applications of carbaryl at 0.31 and 0.69 lb/acre.

Some studies have shown decreased chick survival and body weights in pheasant and quail caused by various exposure levels to carbaryl (DeWitt and Menzie, 1961 and Bursian and Edens, 1977, both as cited in EPA, undated).

Doane and Schaefer (1971) suggested that the reduction in insect populations may reduce the avian food chain in a sprayed area and cause displacement and lowered survival of avian species.

Carbaryl is highly toxic to honey bees. The LD_{50} is 1.34 ug/bee for carbaryl dust and 1.02 ug/bee for Sevin 4-Oil (Atkins et al., 1973). Field studies indicate that bees may be killed by direct contact with treated surfaces. Young and reproductive members of a hive may be killed by eating contaminated pollen that has been brought back to the hive by worker bees (Dobroski, 1985). Adverse impacts to bees may be avoided if the colonies are moved temporarily out of the area to be sprayed or if alternate pollen sources, such as corn pollen, are made available (Dobroski, 1985).

Petroleum Distillates (Diesel Oil and Kerosene). Kerosene and diesel oil are very slightly toxic to mammals based on the acute oral LD_{50}'s in rats of greater than 28,000 mg/kg and 7,380 mg/kg, respectively (HSDB, 1987b; Beck et al., 1982). Toxic effects include loss of muscle coordination, nausea, languor, drowsiness, rapid heart beat, and shallow respiration (ITII, 1976). Diesel oil is extremely irritating to the skin of rabbits but nonirritating to the eyes (Beck et al., 1982). Kerosene is mildly irritating to the skin and eyes of rabbits and nonsensitizing in guinea pigs (Beck et al., 1982). Dermal exposure to 6,560 mg/kg of diesel oil for 3 weeks caused a 67-percent mortality rate in rabbits (API, 1982). Dermal exposure to kerosene for 28 days caused skin and liver lesions in rabbits at the highest dose tested of 2,000 mg/kg but not at the next highest dose of 1,000 mg/kg (API, 1983). Other adverse effects to the skin of the treated animals were observed at all three doses tested (200, 1,000, and 2,000 mg/kg), including cracking, scab formation, necrosis, and ulcerations (API, 1983). No teratogenic effects were observed in rats when exposed to kerosene and diesel vapors during gestation (Mecler and Beliles, 1979; Beliles and Mecler, 1982).

Diesel oil is very slightly toxic to birds when ingested based on the acute oral LD_{50} of greater than 16,400 mg/kg (greater than 20ml/kg) in mallards (Hudson et al., 1984). The toxic effects included weakness, diarrhea, and regurgitation. However, diesel oil appears to cause adverse reproductive effects in birds. Traces of oil in a mallard's diet sharply reduce egg production (Biderman and Dury, 1980), as cited in U.S. Department of Energy, 1983). Application of only 1 microliter (ul) of No. 2 fuel oil on mallard eggs significantly reduced survival and hatchability (Szaro et al., 1978). In the same study, application of 5 ul reduced hatching success to 18 percent, and 20 ul killed all embryos. Similar toxicity was noted in pheasant eggs sprayed with diesel oil (Kopischke, 1972). Death appears to be related to the aromatic portion of the oil rather than the aliphatic portion (Szaro et al., 1978; Hoffman and Albers, 1984). In addition, oil carriers increase the toxicity of pesticides to eggs, apparently by increasing penetration through the shell and membrane (Hoffman and Albers, 1984).

Kerosene was not lethal when applied to mallard eggs at doses of 1 to 50 ul/egg (Hoffman and Albers, 1984). The low toxicity observed in this study was believed to be related to the lower aromatic hydrocarbon content of kerosene (Hoffman and Albers, 1984).

Diesel oil is highly toxic to insects based on high mortality of honey bees during the first 24 hours after spray treatment (Moffet et al., 1972). No information was available on the toxicity of kerosene to honey bees. Kerosene and diesel oil, when used as solvents or adjuvants, also have been observed to increase the toxicity of insecticides (Lagier et al., 1974; Tsuda and Okuno, 1985).

Bacillus thuringiensis. B.t. formulations currently used by the Forest Service are generally nontoxic to mammals because these formulations do not contain the alpha- or beta-exotoxins that have been associated with toxic effects. No fatalities or sublethal toxic effects were observed in several acute, Yubchronic, and chronic laboratory studies using various administration routes (Sassaman, 1987), except for one study showing skin irritation in rabbits following application of 7.2 g/kg in an acute dermal toxicity study (Sassaman, 1987). The delta-endotoxin produced by *B.t.* is toxic to larvae of lepidopteran insects (butterflies and moths), coleopterans (beetles), and to some dipterans (flies and mosquitoes).

Aquatic Species Hazards

Carbaryl. The toxicity of the technical formulation of carbaryl is greater than the 49-percent oil dispersion formulation (Sevin 4-Oil). The acute aquatic toxicity of carbaryl is relatively low when compared to other insecticides. Members of the catfish (Ictaluridae) and minnow (Cyprinidae) families are nearly 10 times more tolerant of carbaryl than the trout (Salmonidae) family. The toxicity to sunfish and bass (Centrarchidae) is approximately midway in this range.

Acetylcholinesterase (AChE) depression (13 to 22 percent) has been observed in brook trout within 24 hours of spraying carbaryl at 1 lb/acre. Levels returned to normal within 48 hours. At the same application rate, Atlantic salmon (*Salmon salar* C.) showed average AChE depression of 20 percent. Levels did not return to normal within 48 hours (Hulbert, 1978; Marancik, 1976).

Some aquatic insects in the orders Plecoptera (stoneflies) and Ephemeroptera (mayflies) are highly sensitive to low levels of carbaryl. Trichoptera (caddisflies) and Diptera (true flies) also are sensitive to carbaryl. There may be a 50- to 100-percent reduction in aquatic insect populations in treated streams and ponds (Burdick et al., 1960). Mount and Oehme (1981) found that applications of 1.25 pounds of carbaryl per acre were not directly toxic to fish, but food items were reduced by 97.2 percent. LOTEL (1975) reported that in a stream treated with 1 pound of carbaryl per acre, each sampling station recorded a residue of at least 40 ppb and a peak residue of 80 ppb. The biological impact was indicated by increased drift of dead and dying stoneflies, mayflies, caddisflies, and true flies.

The effects of 2 consecutive years of spraying on other aquatic organisms appear similar to those observed in areas treated just once (Trial, 1978, 1979; Courtemanch and Gibbs, 1978). These effects include loss of stonefly species from individual streams and altered generic assemblages for an indefinite period (Trial, 1978, 1979). A study of buffered streams by McCullough and Stanley (1980) during the 1979 Maine spruce budworm spray project indicated that benthic invertebrate fauna were not adversely affected. Also, the numbers of drifting invertebrates were substantially lower than in previous years. The long-term impact appears to be a function of species susceptibility and recolonization ability. Two consecutive years of spraying with carbaryl reduced populations of stonefly and susceptible mayfly genera to near zero.

Carbaryl (Sevin 4-Oil) was applied to woodland ponds in Maine at a rate of approximately 1.85 lb a.i./acre (0.84 kg a.i./acre). Caddisfly populations were temporarily reduced. Most severely affected were the amphipods (*Hyallela azteca*), which were nearly reduced to zero. This group failed to recolonize in some ponds for up to 30 months after spraying (Gibbs et al., 1984).

Carbaryl was nontoxic to a species of fresh-water algae at 1 ppm. The growth rate of the algae actually increased after exposure to carbaryl; this was thought to be a result of the increase in available nitrogen (an important plant nutrient) from the degradation of carbaryl (Stadnyk et al., 1971). An increase in algae growth rate after exposure to carbaryl also was reported by Murray and Guthrie (1980).

Concentrations of approximately 10 ppm carbaryl were lethal to three of five species of marine algae. Reproduction was not affected at 1.0 ppm. In one of the five species, growth was inhibited at 0.01 ppm (Ukeles, 1962).

Petroleum Distillates (Kerosene and Diesel Oil). Diesel fuel, jet fuels, and fuel oils are moderately to highly toxic to fish (based on the toxicity categories of EPA, 1985). Jenkins et al. (1977, as cited in Burks, 1982) studied the acute and chronic toxicity of jet fuels to several fish species. They reported 96-hour LC_{50}'s (static tests) for the golden shiner (Notemigonus crysoleucas) of 0.68 and 0.94 mg/L for the jet fuels RJ-4 (a 12-carbon molecule) and RJ-5 (a 14-carbon molecule), respectively. They also reported a 97-day nonlethal concentration for rainbow trout (Salmo gairdnerii) of less than 0.03 mg/L for RF-4 and 0.04 mg/L for RJ-5; and a no-effect level for eggs of the flagfish (Jordanella floridae) exposed by continuous flow to RJ-4 of 0.2 mg/L. Reduced hatchability was observed in flagfish eggs from exposure to RJ-5 at concentrations greater than 0.05 mg/L.

Acute toxicity tests with freshwater fish showing 96-hour LC_{50}'s of greater than 0.19 mg/L for diesel fuel and greater than 1.2 mg/L for No. 2 fuel oil have been reported by EPA (1976, as cited in DOE 1983). Tagatz (1961, as cited in Burks 1982) reported much lower toxicity, with a 48-hour LC_{50} for No. 2 fuel oil of 125 to 251 mg/L with juvenile American shad. His reported LC_{50} is based on the amount of oil applied to the surface of the water (nominal concentration) and not the water soluble fraction; this may account for the apparent lower sensitivity of the shad.

The toxicity of No. 2 fuel oil has been studied for a number of marine fish and invertebrate species (table 2-10). The LC_{50}'s range from 0.81 to more than 6.9 ppm for marine fish and 0.21 to 14.1 ppm for invertebrates (Connell and Miller, 1984). The range of toxicity values determined for No. 2 fuel oil with marine species is useful in estimating the range of sensitivities for freshwater species because marine and freshwater species generally have a similar range of tolerance to toxicants (Sprague, 1985).

Irwin (1964, as cited in Burks 1982) calculated a "ratio of resistance" to allow the ranking of the sensitivities of 57 fish species to oil refinery wastewater. The guppy *(Lebistes reticulatus)* was least sensitive and was assigned a ratio of resistance of 100. The ratios of resistance for some of the common freshwater fish were as follows: rainbow trout (*Salmo*

gairdnerii), 34.68; smallmouth bass (*Micropterus dolomieui*), 35.60; northern pike (*Esox lucius*), 37.31; fathead minnow (*Pimephales promelas*), 49.19; largemouth bass (*Micropterus salmoides*), 53.27; bluegill (*Lepomis macrochirus*), 54.10; and channel catfish (*Ictalurus punctatus*), 60.15. This study may be useful in predicting the relative order of sensitivities of these species to diesel fuels and other petroleum products.

The 96-hour LC_{50} for adult blue crabs (*Callinectes sapidus*) exposed to No. 2 fuel oil was 14.1 mg/L. No histopathological changes were observed in the gills, hepatopancreas, or muscles of the blue crab after 2 weeks of exposure to No. 2 fuel oil at 0 to 1 ppm (Melzian, 1983).

A spill of No. 2 fuel oil into a small stream in Virginia was acutely toxic to some fish, crayfish, and caddisflies. At 2 weeks after the spill the density of benthic macroinvertebrates downstream was 25 percent less than the density upstream from the spill, but species diversity was not affected. The density of the macroinvertebrates had returned to normal levels by 18 weeks after the spill (Hoehn et al., 1974, as cited in Burks, 1982).

Bacillus thuringiensis. There are no data on the hazards of *B.t.* to aquatic species.

Exposure Analysis

Exposures were not calculated for *B.t.* The toxicity is so low that the probability of adverse effects to wildlife or aquatic species is negligible. *B.t.* risk to nontarget insects is discussed in the risk analysis section.

Wildlife Exposures

Realistic and extreme acute exposure estimates were made for each representative species for each of the three major exposure routes: inhalation, dermal, and ingestion. Because the insecticides degrade relatively rapidly and sites are normally treated once per year, no analysis of chronic wildlife dosing was done. Because the insecticides show no tendency to bioaccumulate, long-term persistence in food chains and subsequent toxic effects were not considered a problem and were not examined in the risk analysis.

Insecticide doses for the representative species were calculated using conservative, simplified assumptions concerning routine application operations that give realistic dose estimates and higher (extreme) dose estimates in which animals are directly sprayed. Exposures for realistic and extreme cases were based on the typical and maximum insecticide application rates.

For realistic doses, dermal exposures were based on the insecticide residue levels likely to be found on vegetation leaf surfaces because the animals are assumed to seek cover during a spraying operation. Extreme dose levels were estimated by assuming that animals do not seek cover and thus receive the full insecticide application rate on their entire body surface.

Realistic ingestion doses were assumed to come from animals eating a specified percentage of their daily food intake in contaminated items based on their body size. That is, the percentage of contaminated food intake decreases as body size increases because larger animals are assumed to be more far ranging in obtaining food and would therefore be more likely to obtain some part of their diet away from the sprayed area. In the extreme case, the animals are assumed to feed entirely on contaminated food items.

Inhalation exposures are assumed to come from a hypothetical amount of insecticide droplets forming a "cloud" that moves slowly offsite. The total systemic dose to each animal was calculated as the sum of the estimated doses received by way of dermal, ingestion, and inhalation routes.

Aquatic Species Exposures

Representative species typical of aquatic habitats in the U.S. Forest Service Region 6 were used to estimate risk to aquatic organisms. These organisms were assumed to be exposed to insecticide and petroleum distillate residues by immersion in bodies of water.

EEC's also were calculated for a spill of a 200-gallon load of mixture into a 1-acre pond and for direct spraying of a pond at the full application rate.

Risk Analysis

Wildlife

Carbaryl. None of the realistic or extreme wildlife doses of carbaryl exceed the EPA risk criterion of 1/5 LD_{50}, so wildlife are not at risk from carbaryl in this program. The risks that were calculated for carbaryl to wildlife are in table W-3.

Petroleum Distillates (Diesel Oil and Kerosene). Wildlife exposures are far below the EPA risk levels for these two chemicals, so they represent no risk to wildlife in this program. Diesel oil and kerosene risks to wildlife are summarized in tables W-4 and W-5.

Bacillus thuringiensis. Available studies indicate that *B.t.* is relatively nontoxic to all vertebrate forms. However, nontarget insects are at risk. Certain species such as the cinnabar moth, which is used as a control of tansy ragwort, may be affected by *B.t.* application.

Other desirable species, such as rare butterflies, also could be affected. The U.S. Fish and Wildlife Service identifies endangered and threatened species of invertebrates, and the Forest Service would cooperate to mitigate the effects of *B.t.* applications on endangered or threatened lepidopteran.

Carbaryl. The results of the risk analysis indicate that there is no significant risk of acute adverse effects to any of the representative aquatic species for typical and worst case exposures resulting from carbaryl drift. All Q-values are less than 0.1, as shown in table W-6.

Very limited information is available on the chronic toxicity of carbaryl to aquatic species. In the absence of chronic toxicity information, the likelihood of long-term exposure to insecticide residues was evaluated. The fraction of initial insecticide residue remaining in water was calculated for 1, 2, and 3 weeks after insecticide application using insecticide degradation rates reported in the literature. Less than 10 percent of the initial residue remains at 3 weeks for carbaryl. In streams and other lotic (flowing) waters, insecticide concentrations would quickly be reduced by dilution and transport.

EEC's were calculated for an accidental spill of a helicopter load of 758 liters (200 gallons) of insecticide mixture into a 1-acre pond. Fish are not expected to experience adverse acute effects from a spill of carbaryl. However, some species of aquatic invertebrates are likely to be killed or suffer severe acute effects.

Estimated insecticide concentrations in a pond that is accidentally directly sprayed at worst case application rates are less than those estimated for the pond spill. No significant adverse effects are expected from direct spraying of a pond at worst case rates for carbaryl.

The results of the risk analysis to aquatic species from accidents involving carbaryl are summarized in table W-7.

Petroleum Distillates (Diesel Oil and Kerosene). Based on the most conservative acute toxicity value, aquatic organisms are at slight risk from the petroleum distillates (kerosene and diesel oil combined) under typical conditions. Under worst-case conditions, aquatic organisms are at significant risk of adverse effects from petroleum distillates. Results of the acute toxicity risk analysis for petroleum distillates are summarized in table W-8.

Risks for chronic toxicity to aquatic species from petroleum distillates are summarized in table W-9. Significant risks may be posed to several aquatic species if the body of water is stagnant, such as a pond. In fast-moving streams, dilution and transport would quickly reduce petroleum distillate concentrations below the levels at which significant chronic risks to aquatic species may occur.

A spill of diesel oil and kerosene into a 1-acre pond could likely result in a severe kill of fish and aquatic invertebrates. Aquatic organisms are at significant risk of acute adverse effects from direct spraying of petroleum distillates. The results of accidental exposures to petroleum distillates by aquatic species are summarized in table W-10.

Bacillus thuringiensis. Aquatic species are not considered to be at risk from *B.t* applications, based on *B.t.*'s low vertebrate toxicity.

Summary of Effects of the Alternatives on Wildlife and Aquatic Species

Alternative 1 - No Action

Alternative 1 would have no direct effects on wildlife and aquatic species. A number of wildlife species may be indirectly affected because spruce budworm would seriously affect forest habitats if left unchecked.

Alternative 2 - Direct Suppression with *B.t.*

Risks to wildlife or aquatic species from Alternative 2 should be low because of the low toxicity of *B.t.* to vertebrates. Risks to butterflies, moths, beetles, flies, and mosquitoes would be significant. Indirect effects to insectivorous vertebrates are possible for those species that feed on these insects.

Alternative 3 - Direct Suppression with Carbaryl

Alternative 3 poses higher risks to wildlife and aquatic species than the other alternatives, since the use of carbaryl may kill or affect the behavior and survival/reproductive ability of individual animals. The petroleum distillates also pose some risk, particularly to aquatic species.

Alternative 4 - Direct Suppression with *B.t.* and/or Carbaryl

Alternative 4 poses risks intermediate to those of alternatives 2 and 3. The extent of risk depends on the proportion of use of the two treatment methods.

Table W-1

Representative Wildlife and Domestic Species

Representative Niche	Representative Species
Insectivorous birds	Flicker
Granivorous birds	Dove
Omnivorous birds	Jay
Piscivorous birds	Kingfisher
Carnivorous birds	Owl
Small omnivorous mammals	Mouse
Medium herbivorous mammals	Rabbit
Large herbivorous mammals	Deer
Carnivorous mammals	Fox
Insectivorous amphibians	Toad
Carnivorous reptiles	Snake
Domestic animals	Cattle
	Chicken
	Dog

Table W-2

Representative Aquatic Species Used in the Analysis

Common Name	Scientific Name
Rainbow trout	*Salmo gairdnerii*
Brook trout	*Salveliuus fontinalis*
Cutthroat trout	*Salmo clarki*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieui*
Bluegill	*Lepomis macrochirus*
Yellow perch	*Perca flavescens*
Water flea	*Daphia* sp.
Stonefly	*Plecoptera* sp.
Scud	*Gammarus* sp.

Table W-3

Carbaryl Wildlife Risk

Representative Species	Realistic Dose (mg/kg)	Extreme Dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference Species
Flicker	1.1	11.0	156	780	Grouse
Dove	0.9	8.8	156	780	Grouse
Jay	1.2	11.0	156	780	Grouse
Kingfisher	0.5	4.7	156	780	Grouse
Screech owl	1.5	15.0	156	780	Grouse
Mouse	3.3	32.0	55	275	Mouse
Rabbit	0.4	5.7	142	710	Rabbit
Deer	0.1	1.1	40	200	Mule deer
Fox	0.3	2.6	30	150	Cat
Toad	1.5	14.6	156	780	Grouse
Snake	1.9	18.2	156	780	Grouse
Cow	0.0	1.4	40	200	Mule
Chicken	0.2	1.5	156	780	Grouse
Dog	0.1	0.5	30	150	Cat

Table W-4

Diesel Oil Wildlife Risk

Representative Species	Realistic Dose (mg/kg)	Extreme Dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference Species
Flicker	4	40.4	3,280	16,400	Mallard
Dove	3.3	32.8	3,280	16,400	Mallard
Jay	4.2	41.7	3,280	16,400	Mallard
Kingfisher	1.9	18.9	3,280	16,400	Mallard
Screech owl	5.5	54.8	3,280	16,400	Mallard
Mouse	11.3	113	1,476	7,380	Rat
Rabbit	1.6	21.3	1,476	7,380	Rat
Deer	0.2	4.3	1,476	7,380	Rat
Fox	1	10.3	1,476	7,380	Rat
Toad	11.8	118	3,280	16,400	Mallard
Snake	15	150	3,280	16,400	Mallard
Cow	0.15	4.9	1,476	7,380	Rat
Chicken	0.63	6.7	3,280	16,400	Mallard
Dog	0.3	2.9	1,476	7,380	Rat

Table W-5

Kerosene Wildlife Risk

Representative Species	Realistic Dose (mg/kg)	Extreme Dose (mg/kg)	1/5 LD_{50}	LD_{50}	Reference Species
Flicker	1.1	11.6	3,280	16,400	Mallard
Dove	0.09	9.5	3,280	16,400	Mallard
Jay	1.2	12	3,280	16,400	Mallard
Kingfisher	0.5	5.5	3,280	16,400	Mallard
Screech owl	1.6	15.8	3,280	16,400	Mallard
Mouse	3.2	32.5	5,600	28,000	Rat
Rabbit	0.5	6.1	5,600	28,000	Rat
Deer	0.06	1.2	5,600	28,000	Rat
Fox	0.3	3	5,600	28,000	Rat
Toad	3.3	34	3,280	16,400	Mallard
Snake	4.2	43.2	3,280	16,400	Mallard
Cow	0.04	1.4	5,600	28,000	Rat
Chicken	0.18	1.9	3,280	16,400	Mallard
Dog	0.08	0.8	5,600	28,000	Rat

Table W-6

Acute Toxicity Risk Analysis for Carbaryl

Representative Species	Risk Level[1/,2/]
Typical concentration, (EEC) = 0.0091 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	No risk
Stonefly	No risk
Scud	No risk
Worst-case concentration, (EEC) = 0.056 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	No risk
Stonefly	No risk
Scud	No risk

1/ Source: EPA, 1986

2/ Based on calculated LC_{50} or EC_{50} (ppm) and Q-value (EEC/LC_{50}).

Table W-7

Carbaryl Risk From Accidents

Representative Species	Risk Level[1/,2/]
200 gallon spill into pond, EEC = 38 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	Significant
Stonefly	Significant
Scud	Significant
Direct spraying of water body at maximum rate, EEC = 0.094 ppm	
Rainbow trout	No risk
Brook trout	No risk
Cutthroat trout	No risk
Largemouth bass	No risk
Smallmouth bass	No risk
Bluegill	No risk
Yellow perch	No risk
Water flea	No risk
Stonefly	No risk
Scud	No risk

1/ Source: EPA, 1986

2/ Based on calculated LC_{50} or EC_{50} (ppm) and Q-value (EEC/LC_{50}).

Table W-8

Acute Toxicity Risk Analysis for Petroleum Distillates

Representative Species	Risk Level[1/,2/]
Typical concentration, (EEC) = 0.038 ppm	
Rainbow trout	Slight
Brook trout	Slight
Cutthroat trout	Slight
Largemouth bass	Slight
Smallmouth bass	Slight
Bluegill	Slight
Yellow perch	Slight
Water flea	Slight
Stonefly	No data
Scud	No data
Worst-case concentration, (EEC) = 0.24E pmm	
Rainbow trout	Significant
Brook trout	Significant
Cutthroat trout	Significant
Largemouth bass	Significant
Smallmouth bass	Significant
Bluegill	Significant
Yellow perch	Significant
Water flea	Significant
Stonefly	No data
Scud	No data

1/ Source: EPA, 1986

2/ Based on LC_{50} or EC_{50} (ppm) and Q-value (EEC/LC_{50}).

Table W-9

Chronic Toxicity Risk Analysis for Petroleum Distillates

Representative Species	Risk Level[1/], [2/]
Typical concentration, (EEC) = 0.038 ppm	
Rainbow trout	Significant
Brook trout	Significant
Cutthroat trout	Significant
Largemouth bass	Significant
Smallmouth bass	Significant
Bluegill	Significant
Yellow perch	Significant
Water flea	No data
Stonefly	No data
Scud	No data
Worst case, (EEC) = 0.24 ppm	
Rainbow trout	Significant
Brook trout	Significant
Cutthroat trout	Significant
Largemouth bass	Significant
Smallmouth bass	Significant
Bluegill	Significant
Yellow perch	Significant
Water flea	No Data
Stonefly	No Data
Scud	No Data

1/ Source: EPA, 1986

2/ Based on MATC or NOEL (ppm) and Q-value (EEC/LC_{50}).

Table W-10

Petroleum Distillates Risk from Accidents

Representative Species	Risk Level[1/], [2/]
200 gallon spill into pond, EEC = 160 ppm	
Rainbow trout	Significant
Brook trout	Significant
Cutthroat trout	Significant
Largemouth bass	Significant
Smallmouth bass	Significant
Bluegill	Significant
Yellow perch	Significant
Water flea	Significant
Stonefly	No Data
Scud	No Data
Direct spraying of water body at maximum rate, EEC = 0.40 ppm	
Rainbow trout	Significant
Brook trout	Significant
Cutthroat trout	Significant
Largemouth bass	Significant
Smallmouth bass	Significant
Bluegill	Significant
Yellow perch	Significant
Water flea	Significant
Stonefly	No Data
Scud	No Data

1/ Source: EPA, 1986

2/ Based on LC^{50} or EC^{50} (ppm) and Q-value (EEC/LC_{50}).

APPENDIX R

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APPENDIX S

Glossary

A

ABSORPTION
The taking in and incorporating; assimilation.

ACCEPTABLE DAILY INTAKE (ADI)
The maximum dose of a substance anticipated to be without lifetime risk to humans when taken daily.

ACEPHATE
Organophosphate insecticide; the active ingredient found in insecticide formulations sold under the trade name, Orthene.

ACETYLCHOLINE
A compound that is released at many autonomic nerve endings. It is believed to function in the transmission of the nerve impulse.

ACETYLCHOLINESTERASE
An enzyme released at nerve endings in order to accelerate hydrolysis of acetylocholine, thereby ending nerve stimulation after an impulse has passed.

ACTINEDID MITE
Mites belonging to the family Actinedidae; usually represented by species living in soil and leaf litter.

ACTIVE INGREDIENT (AI)
The effective part of a pesticide formulation, or the actual amount of the technical material present in the formulation.

ACUTE HEALTH EFFECTS
Health effects that are immediate and obvious.

ACUTE TOXICITY
The toxicity of a compound when given in a single dose, or in multiple doses, over a period of 24 hours or less.

ADSORPTION
Adhesion of the molecules of a substance to the surface of another medium.

ADVERSE
Any action which is antagonistic or opposite to the preferred action.

AI
Abbreviation for active ingredient

ALIMENTARY
Connected with food or nutrition; referring to the digestive system.

ALLOWABLE DAILY INTAKE
Synonym of acceptable daily intake.

ALLUVIUM
A general term for all material deposited by streams.

ALTERNATIVE
One of several policies, plans, or projects proposed for decisionmaking.

ANADROMOUS FISH
Those species of fish, spawned in fresh water, which mature in the sea, and migrate back into fresh water streams to spawn. Salmon, steelhead, and shad are examples.

ANAEROBIC
Lacking in free oxygen.

ANALYSIS UNIT
A specific parcel of land considered as a single unit for treatment of spruce budworm infestation.

ANIMAL UNIT
Considered to be one mature (1,000 lb) cow, or the equivalent, based upon average daily forage consumption of 26 lbs dry matter per day.

ANIMAL UNIT MONTH (AUM)
The forage requirement for 1 month for a 1,000-lb mature animal (cow), or its equivalent, based upon average daily forage consumption of 26 lbs dry matter per day.

APIARY
A place where bees are kept. Beehives.

ARTHROPODS
Major group of invertebrate animals belonging to the phylum Arthropoda. This group includes insects, spiders, and crustaceans.

AUM
See Animal Unit Month.

AVAILABLE
Land which has not been administratively or legislatively withdrawn from timber production.

AVAILABLE FORAGE
The amount of forage which may be removed without adversely affecting the vigor of the forage plants. (Normally considered to be about 50 percent of a grass plant.)

AVIAN
Pertaining to birds.

B

BACILLUS THURINGIENSIS (*B.T.*)
Scientific name of the active ingredient of a bacterial insecticide which is a formulation of spores and unique crystalline bodies produced by the bacterium. The active ingredient in biological insecticides sold under such names as Dipel[R], Bactospeine[R] and Thuricide[R]. It acts as a stomach poison to leaf-eating lepidopterous insects (moths and butterflies) as the crystal dissolves and paralyzes the gut wall, causing the larvae to stop feeding.

BACKGROUND
The visible terrain beyond the foreground and middleground where individual trees are not visible but are blended into the total fabric of the forest stand (see Foreground and Middleground).

BENEFIT
(Value) Inclusive term used to quantify the results of a proposed activity, program, or project, expressed in monetary or nonmonetary terms.

BENEFIT-COST RATIO
(Cost efficient) Measure of economic efficiency, computed by dividing total discounted benefits by total discounted costs.

BIG GAME
Large mammals hunted for recreation or meat; refers to elk and deer when used in this document and not otherwise qualified.

BINOMIALLY DISTRIBUTED
Statistical term defining a population of numbers (data or events) having two unique characteristics.

BIOACCUMULATION
The uptake and temporary storage of a chemical in animal flesh and organs. Over a period of time, a higher concentration of chemical may be found in the organism than in the environment.

BIOCONCENTRATION
The increase in the concentration of a chemical within organisms as it moves up through the food chain.

BIOMASS
The sum weight or volume of all living organisms in a given area.

BIOTA
The animal or plant life of a region or area.

BISECTED
To divide into two equal parts.

BOVINE
Referring to cattle.

BRACONID
Members of the wasp family Braconidae - small, usually parasitoid wasps that are largely beneficial to man.

BRADYCARDIA
Abnormally slow beating of the heart.

B.T.
Abbreviation for *Bacillus thuringiensis.*

BUFFER ZONES OR AREAS
Usually set around sensitive areas such as lakes, streams, or ponds that are not directly treated with insecticides; or areas set around the same, including people who object to chemical insecticides, that are treated instead with microbial insecticides such as B.T. In some cases, may refer to areas actually treated, such as treatment of buffer zones along roads.

C

CADDISFLY
A small moth-like insect. The larvae live in fresh water in portable cases they construct around themselves. Member of order Trichoptera.

CANOPY
The uppermost spreading, branchy layer of a forest.

CARBAMATE
A salt or ester of carbamic acid.

CARBARYL
Carbamate insecticide; the active ingredient in insecticide formulations sold under the trade name Sevin[R.] Carbaryl expresses contact and stomach poison action on target insects and shows relatively long residual effects.

CARCINOGENICITY
Tendency of a substance to cause cancer.

CELLULOSE
An inert substance which forms the main portions of cell walls in plants.

CEQ
Council on Environmental Quality.

CHEMICAL HYDROLYSIS
A chemical reaction where a substance reacts with the ions of water to produce a weak acid, a weak dose, or both.

CHITIN
A semi-transparent horny substance forming the principal component of crustacean shells, insect exoskeletons, and the cell walls of certain fungi.

CHININASE
An enzyme that hydrolyzes chitin.

CHOLINESTERASE
See acetylcholinesterase.

CHORISTONEURA OCCIDENTALIS
Scientific name of the western spruce budworm.

CHRONIC HEALTH EFFECTS
Health effects that may take repeated exposures over a period of months or years before becoming apparent. Chronic health effects may blend into the general health problems of life and never be detected.

CHRONIC TOXICITY
The effect of a compound on test animals when exposed to sublethal amounts continually. Usually, daily exposures over a period of time: weeks, months, or years.

CISTERN
A water storage reservoir.

CLASS I STREAM
Perennial or intermittent streams (or segments thereof) that are direct sources of water for domestic use, or are used by large numbers of fish for spawning, rearing, or migration, or flow enough water to be a Class I stream.

CLASS II STREAM
Perennial or intermittent streams (or segments thereof) that are used by moderate, though significant, numbers of fish for spawning, rearing, or migration, have a moderate influence on a Class I stream, or are a major contribution to a Class II stream.

CLASS III STREAM
All other perennial streams or segments thereof not meeting higher class criteria.

CLASS IV STREAM
All other intermittent streams not meeting higher class criteria.

CLEARCUTTING
Removal of virtually all trees, large or small, in a timber stand in one cutting operation. Leads to the establishment of an even-aged stand.

CLIMAX
The culminating stage in plant succession for a given site where the vegetation has reached a highly stable condition.

CLIMAX SPECIES
Those species that dominate the forest stand in either numbers per unit area or biomass at climax.

CODE OF FEDERAL REGULATIONS (CFR)
The listing of various regulations pertaining to management and administration of National Forests.

COLLEMBOLA
(Springtails) Primitive, wingless group of insects commonly found in soil and duff.

COMMERCIAL FOREST LAND
Forest land tentatively suitable for the production of continuous crops of timber and that has not been withdrawn.

COMMERCIAL THINNING
Any type of thinning of trees producing merchantable material at least equal to the value of the direct costs of timber harvesting.

COMMODITY
A transportable resource product with commercial value; all resource products which are articles of commerce.

COMMUNITY TYPES
A generalized category comprised of a number of similar stands of vegetation or animal life.

COMPACTION
The packing together of soil particles by forces exerted at the soil surface.

CONCERN
A point matter, or question raised by management, that must be addressed in the planning process.

CONFLAGRATION
A large and destructive fire (see Wildfire).

CONSENSUS
A process in which a mutually agreeable opinion is reached by a variety of individuals concerning an issue.

COST EFFICIENCY
The usefulness of specified inputs (costs) to produce specified outputs (benefits). In measuring cost efficiency, some outputs, including environmental, economic, or social impacts, are not assigned monetary values but are achieved at specified levels in the least cost manner. Cost efficiency is usually measured using present net value, although use of benefit-cost ratios and rates of return may be appropriate. (36 CFR 219.3)

COST FIXED
A cost that is committed for the time horizon of planning or the decision being considered. Fixed costs include fixed ownership requirements, fixed protection, short-term maintenance, and long-term planning and inventory costs.

COST, INVESTMENT
A cost of creating or enhancing capital assets, including costs of administrative or common-use transport facilities and resource management investments.

COST, NON-FOREST SERVICE
A cost of investment and operating activities paid by cooperators or other non-Forest Service agencies, which are part of Forest Service management programs, or which contribute to the outputs included in the analysis.

COST, OPERATIONAL
For the National Forest System, a cost of activities to plan and manage controlled outputs, and for long-term protection and maintenance of capital assets. For State and

private forestry and research, operational costs include program activity costs. They are variable costs.

COST PLUS NET RESOURCE VALUE CHANGE
(C+NVC) Cost including both the fixed annual cost for the protection organization (annual fire program budget) and the variable suppression (emergency fire fighting) costs; NVC is the difference in value of planned resource outputs on an area before and after a fire.

COST, VARIABLE
A cost that varies with the level of controlled outputs in the time horizon covered by the planning period or decisions being considered. Variable costs include investment, operational, and variable general administration.

COVER
Vegetation used by wildlife for protection from predators, to ameliorate conditions of weather, or in which to reproduce. See Hiding Cover; Thermal Cover.

COVER/FORAGE, COVER-FORAGE AREA RATIO
The ratio, in percent, of the amount of area in forage condition to that area in cover condition; the criteria by which potential deer and elk use of an area is judged.

CRITICAL HABITAT
For threatened or endangered species, the specific areas within the geographical area occupied by the species (at the time it is listed, in accordance with provisions of Section 4 of the Endangered Species Act) on which are found those physical or biological features essential to the conservation of the species. This habitat may require special management considerations or protection. Protection may also be required for additional habitat areas outside the geographical area occupied by the species at the time it is listed, based upon a determination of the Secretary of the Interior that such areas are essential for the conservation of the species.

CROP TREE
Any tree forming, or selected to form, part of the final crop; generally a tree selected in a young stand for that purpose.

CROWN FIRE
A fire that runs through the tops of trees, scrub, or brushwood.

CULMINATION OF MEAN ANNUAL INCREMENT
(CMAI) The age at which the annual increment of growth of a timber stand reaches its maximum.

CULTURAL RESOURCES
Buildings, sites, areas, architecture, memorials, and objects having scientific, prehistoric, historic, or social values.

CUMULATIVE EFFECTS
The combined effects of two or more management activities. The effects may be related to the number of individual activities, or to the number of repeated activities on the same piece of ground. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time.

CURRENT DIRECTION
The existing direction in approved management plans; continuation of existing policies; standards and guidelines; current budget updated for changing costs over time; and, to the extent possible, production of current levels and mixes of resource outputs.

D

DBH
See Diameter at Breast Height

DECISION NOTICE
A document which announces the decision and resulting actions for a Federal project.

DEFOLIATION
A process in which all leaves are removed from a tree.

DEGRADATION
The breakdown of a chemical compound into simple components. Related to the persistence of the chemical in terms of ability to kill insects or to produce health effects.

DEIS
Draft Environmental Impact Statement

DERMAL
Of the skin.

DESIGNATED AREAS
Principal population centers or other areas requiring protection under State or Federal air quality laws or regulations.

DEVELOPED RECREATION
Outdoor recreation requiring significant capital investment in facilities to handle a concentration of visitors on a relatively small area. Examples are ski areas, resorts, and campgrounds.

DIAMETER AT BREAST HEIGHT (DBH)
The diameter of a tree 4.5 feet above average ground level, except that in National Forest practice it is measured from the highest ground level. Abbreviated dbh. The additional abbreviations, ob and ib, are used to designate whether the diameter refers to the measurement outside or in the bark.

DIPEL (R)
Trade name of biological insecticide formulations containing the bacterium *Bacillus thuringiensis*.

DISCOUNT RATE
An interest rate that represents the cost or time value of money in determining the present value of future costs and benefits.

DISCOUNT RATE, NOMINAL
Discount rate expressed in terms of current dollars, and thus affected by the rate of inflation.

DISCOUNT RATE, REAL
A discount rate adjusted to exclude the effects of inflation.

DISCOUNTING
An adjustment, using a discount rate, for the value of money over time so that costs and benefits occurring in the future are reduced to a common time, usually the present, for comparison.

DISPERSED RECREATION
Outdoor recreation in which visitors are diffused over relatively large areas. Where facilities or developments are provided, they are more for access and protection of the environment than for the comfort or convenience of the people.

DISTAL
Farthest from the center or the point of attachment or origin; terminal: Opposed to proximal.

DIVERSITY
The distribution and abundance of different plant and animal communities and species within the area covered by a land and resource management plan.

DOMESTIC WATERSHED
Any recognized watershed serving less than 25 individuals or for less than 60 days per year.

DOSE-RESPONSE ASSESSMENT
Determines the probability of the adverse outcome for a given level of exposure.

DOSE-RESPONSE RELATIONSHIP
Relationship used in the study of toxic materials. The response (frequency or magnitude of a health effect) is always directly related to the dose.

DRIFT
The movement of air-borne particles from the intended contact area to other areas.

DRIFT DEPOSITION
Derived from actual measurements and assumes conditionswhich meet current guidelines for aerial spraying. Wind direction is assumed directly toward the targets of concern and no allowance is made for insecticide degradation.

DYSFUNCTION
Disordered or impaired functioning of a bodily system or organ

E

EC_{50}
Median effective concentration; concentration (ppm or ppb) of the toxicant in the environment (usually water) which produces a designated effect to 50 percent of the test organisms exposed.

ECOLOGICAL DIVERSITY
The numbers and types of ecological communities contained within a specified area.

ECOLOGICAL PROCESSES
The interaction of environmental systems in promoting change in the environment.

ECOSYSTEM
An interacting system of organisms considered together with their environment; e.g., marsh, watershed, and lake ecosystems.

EDGE
The boundary between two or more elements of the environment; e.g., field and woodland.

EFFECTIVENESS, COST
Achieving specified outputs or objectives under given conditions for the least cost.

EFFECTS
Environmental consequences as a result of a proposed action. Included are direct effects, which are caused by the action and occur at the same time and place, and indirect effects, which are caused by the action and are later in time or further removed in distance, but which are still reasonably foreseeable. Indirect effects may include population growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems.

The terms "Effects" and "Impacts" as used in this statement are synonymous. Effects may be ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic quality, historic, cultural, economic, social, or health-related; whether direct, indirect, or cumulative. Effects resulting from actions may have both beneficial and detrimental aspects (40 CFR 1508.8).

EFFICIENCY, COST
The usefulness of specified inputs (costs) to produce specified outputs (benefits). In measuring cost efficiency, some outputs (such as environmental, economic, or social impacts) are not assigned monetary values but are achieved at specified levels in the least-cost manner. Cost efficiency is usually measured using present net value, although use of benefit-cost ratios and rates-of-return may sometimes be appropriate.

EFFICIENCY, ECONOMIC
The usefulness of inputs (costs) to produce outputs (benefits) and effects when all costs and benefits that can be identified and valued are included in the computations. Economic efficiency is usually measured using present net value, although use of benefit-cost ratios and rates-of-return may sometimes be appropriate.

EIS
Environmental Impact Statement

EMPIRICAL YIELD TABLE
A table showing, for one or more given species on a given site, the progressive development of a timber stand at periodic intervals covering the greater part of its useful life. This table is prepared on the basis of actual average stand conditions.

ENDANGERED SPECIES
Any species of animal or plant which is in danger of extinction throughout all or a significant portion of its range. Not included are members of the class, Insecta, which have been determined by the Secretary of Interior to constitute a pest whose protection under the provisions of this Act (Endangered Species Act of 1973) would present an overwhelming and overriding risk to man. An endangered species must be designated in the Federal Register by the appropriate Federal Agency Secretary.

ENDEMIC
Restricted to and constantly present in a particular locality.

ENDOSPORES
An asexual spore formed within a special spore case.

ENDOTOXIN
A toxic substance found in certain disease-producing bacteria and liberated by the disintegration of the bacterial cell: They harm certain tissue cells.

ENVIRONMENT
The aggregate of physical, biological, economic, and social factors affecting all organisms in an area.

ENVIRONMENTAL ANALYSIS
Procedure defined by the National Environmental Policy Act of 1969 whereby the environmental impacts of a planned action are objectively reviewed.

ENVIRONMENTAL ASSESSMENT
A concise public document which provides sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement or Finding of No Significant Impact. It aids in compliance with the NEPA when no Environmental Impact Statement is needed.

ENVIRONMENTAL IMPACT STATEMENT
A document prepared by a Federal Agency in which anticipated environmental effects of a planned course of action or development are evaluated.

ENVIRONMENTAL PROTECTION AGENCY (EPA)
The Federal Agency with primary responsibility for enforcement of environmental regulations.

EPA
Environmental Protection Agency.

EPHEMERAL STREAM
A stream which dries up during part of the year.

EPIDEMIC
Prevalent and spreading rapidly; widespread.

EPIDEMIOLOGY
Originally, the science that studied the cause and control of epidemics of communicable diseases in a region. Now, its subject matter includes diseases caused by chemicals and other environmental factors.

EPIGASTIC
The hindgut: Embryonic structure from which the large intestine is formed.

ERODIBLE
Susceptible to erosion.

EROSION
The wearing away or detachment of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitation creep.

EVEN-AGE MANAGEMENT
The application of a combination of actions that results in the creation of stands in which trees of essentially the same age grow together. Managed even-aged forests are characterized by a distribution of stands of varying ages (and therefore tree sizes) throughout the forest area. The difference in age between trees forming the main canopy level of a stand usually does not exceed 20 percent of the age of the stand at harvest rotation age. Regeneration in a particular stand is obtained during a short period at or near the time the stand has reached the desired age or size for regeneration and is harvested. Clearcut, shelterwood, or seed tree cutting methods produce even-aged stands.

EXPOSURE
The pathways of human exposure to chemicals are dermal, oral, and inhalation.

EXPOSURE ASSESSMENT
Determines the level of exposure for a given agency policy or activity.

EXTRAPOLATION
To infer from known values.

F

FEIS
Final Environmental Impact Statement

FETOTOXICITY
The ability to produce toxic effects in a fetus of humans or animals.

FIRE-DEPENDENT ECOSYSTEM
Ecosystems that require periodic disturbances by fire for maintenance of composition and structure.

FIRE REGIME
Fire's effects on an ecosystem depend upon fire type, frequency, duration, severity, and size. These five items define the characteristic fire regime of an ecosystem.

FIRE RISK
Potential for a fire start, natural or human-caused.

FORAGE
Food for animals.

FOREGROUND
A term used in visual (scenery) management to describe the stand of trees immediately adjacent to a high-value scenic area, recreation facility, or forest highway (see "Background", "Middleground").

FOREST CANOPY
The crown cover or upper foliage of forest trees.

FOREST COMPOSITION
The various combinations of plants which occupy a site in the forest. These plant communities contain a distinct form and function.

FOREST LAND
Land at least 10 percent occupied by forest trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use.

FORMULATION
The form in which a pesticide is packaged or prepared for use.

FRY
Juvenile fish up to the time when the yolk sac has been absorbed.

FS
USDA Forest Service. The Agency responsible for suppression projects.

FUEL
Living or dead plant material that will burn.

FUEL LOADING
The amount of fuel present, expressed quantitatively as weight of fuel per unit area, generally expressed in tons per acre.

FUELS
Any material that will carry and sustain a forest fire, primarily natural materials, both live and dead.

G

GALL MOTHS
Moths characterized by larvae that feed in the interior of plants producing galls (abnormal growths of plant tissue) in which pupation takes place.

GAMASID MITES
Usually predaceous mites of soil and leaf litter.

GAME
Wildlife that are hunted for sport and regulated by State game regulations.

GAVAGE
(Used in testing) Forced feeding, especially through a tube passed into the stomach.

GENERIC ASSEMBLAGES
Groupings of species of a common genera.

GOODS AND SERVICES
The various outputs, including on-site uses, produced from forest and rangeland resources.

GUIDELINE
An indication or outline of policy or conduct.

H

HABITAT
The place where a plant or animal naturally or normally lives and grows.

HALF-LIFE
The time required for half the amount of substance (such as an insecticide) in, or introduced into a living system, to be eliminated whether by excretion, metabolic decomposition, or other natural process.

HERBIVORES
Animals that feed on plants.

HIDING COVER
Vegetation that provides a screening for wildlife from predators. Usually used in conjunction with big-game habitat requirements.

HISTOPATHOLOGIC
Having to do with disease of the tissues.

HYMENOPTERA
A large order of insects comprised of ants, bees, sawflies, and wasps. The typical adult has four membranous wings and chewing type mouthparts.

I

ICHEUMONID WASP
Large varied family of wasps, many of which are parasitic, generally considered beneficial as pest parasitoids or predators.

IMPACT, ECONOMIC
The change, positive or negative, in economic conditions, including distribution and stability of employment and income in affected local, regional, and national economies, which directly or indirectly results from an activity, project, or program.

IMPACT, ECONOMIC, DIRECT
Impacts caused directly by forest product harvest or processing, or forest uses.

IMPACT, ECONOMIC, INDIRECT
Impacts that arise from supporting industries selling goods or services to directly-affected industries.

IMPACT, ECONOMIC, INDUCED
Impacts resulting from employees or owners of directly- or indirectly-affected industries spending their income within the economy.

INERT INGREDIENT
An ingredient in an insecticide that has no active properties or is neutral in its effects upon living organisms.

INHERENT
Those factors that exist in something as a permanent element.

INORGANIC
Any compound which is not derived from carbon. Derived or composed of matter other than plants or animals.

INSECT DRIFT
Movement of dead or dying aquatic insects within a stream; an occurrence of natural mortality that can be dramatically increased with introduction of toxic substances into a stream.

INSECTIVOROUS
Feeding chiefly on insects.

INSTAR
The term for a insect before each of the molts (shedding of its skin) it must go through in order to increase in size. Upon hatching from its egg, the insect is in instar I and is so called until it molts, when it begins instar II, etc.

INTEGRATED PEST MANAGEMENT (IPM)
A process for selecting strategies to regulate forest pests in which all aspects of a pest-host system are studied and weighed. The information considered in selecting appropriate strategies includes the impact of the unregulated pest population on various resource values and alternative regulatory tactics and strategies. Benefit and cost estimates for these alternative-sound silvicultural practices and ecology of the pest-host system are also considerations in development of the management strategy. This strategy consists of a combination of tactics; for example timber stand improvement plus selective use of pesticides. A basic principle in the choice of strategy is that it be ecologically compatible or acceptable.

INTERACTIONS
Mixtures of chemicals may have substantially different toxicity than the sum of the toxicities of the components. The chemicals may interact to increase toxicity (synergism) or to decrease toxicity (antagonism).

INTERDISCIPLINARY TEAM
A team of people that collectively represent several disciplines and whose duty it is to coordinate and integrate the planning activities.

INTERMITTENT STREAMS
Watercourses that contain water only during part of a normal year, usually in the spring and early summer.

INVERTEBRATE
Major group of animals, of which arthropods are members, characterized by the lack of backbone and spinal column.

IN VITRO
In glass (test tube) or otherwise outside a living organism.

IN VIVO
In a living organism.

IPM
Integrated Pest Management.

IRRETRIEVABLE
Applies to losses of production, harvest, or use of renewable natural resources. For example, some or all of the timber production from an area is irretrievably lost during the time an area is used as a winter sports site. If the use is changed, timber production can be resumed. The production lost is irretrievable, but the action is not irreversible.

IRREVERSIBLE
Applies primarily to the use of nonrenewable resources, such as minerals or cultural resources, or to those factors such as soil productivity, that are renewable only over long time periods. Irreversible also includes loss of future options.

ISSUE
A point, matter, or question of public discussion or interest to be addressed or decided through the planning process.

L

LAND MANAGEMENT PLANNING
The process of organizing the development and use of lands and their resources in a manner that will best meet the needs of people over time, while maintaining flexibility for a combination of resources for the future.

LARVA (PLURAL LARVAE)
An insect in the earliest stage of development after it has hatched and before it changes into pupa; a caterpillar, maggot, or grub.

LC_{50}
Median lethal dose; the size of a single dose of a chemical necessary to kill 50 percent of the organisms in a specific test situation. It is usually expressed in the weight of the chemical per unit of body weight (mg/kg). It may be fed (oral LD_{50}), applied to the skin (dermal LD50), or administered in the form of vapors (inhalation LD50).

LD_{50}
Median lethal dose; is the milligram of toxicant per kilogram of body weight (mg/kg) lethal to 50 percent of the test animals to which it is administered under the conditions of the experiment.

LEPIDOPTERA
A large order of insects, including butterflies and moths; characterized by four scale-covered wings and coiled sucking mouthparts.

LOAEL (Lowest Observable Adverse Effect Level)
The lowest dose at which toxic effects can be observed in the test organism. Used in the chronic toxicity assessment.

M

MAINTENANCE
A strategy used in the alternatives requiring relative small doses of energy and resources to perpetuate a stable condition.

MANAGEMENT CONCERN
Any factor which is viewed as being detrimental by management.

MANAGEMENT DIRECTION
A statement that includes: multiple use and other goals and objectives, the associated management strategies, and standards and guidelines for attaining them.

MANAGEMENT INTENSITY
A management practice, or combination of management practices, and associated costs designed to obtain different levels of goods and services.

MANAGEMENT PRACTICE
A specific action, measure, course of action, or treatment.

MANAGEMENT REQUIREMENTS
Actions or activities that are to be conducted in a defined manner.

MANAGEMENT STANDARDS
A unit of measure used to assess the implementation of a management practice or requirement.

MANAGEMENT STRATEGY
Management practices and intensity selected and scheduled for application on a management area to attain multiple use and other goals and objectives.

MARGIN OF SAFETY (MOS)
An arbitrarily established separation between the no-effect level of chemicals found in animal experiments and the level of exposure estimated to be safe for humans. This is used in estimating an Allowable Daily Intake (ADI) by the EPA (Environmental Protection Agency) and FDA (Food and Drug Administration) for tolerances of residues in food and water. A common convention for chemicals is to use a MOS of 100 which means the "safe" level for humans is 100 times less than the no-effect level established in animal experiments.

MASTITIS
Inflammation of the breast or mammary gland.

MATURE TIMBER
Trees that have attained full development, particularly in height, and are in full seed production.

MAXIMUM MODIFICATION (VISUAL)
See Visual Quality Objective.

MBF
Thousand board feet.

METABOLITES
Products of the chemical changes in living cells that provide energy and assimilate new material.

MEXACARBATE
A carbamate insecticide.

MG/KG
Milligrams per kilogram; used to designate the amount of toxicant required per kilogram of body weight of test organisms to produce a designated effect; usually the amount necessary to kill 50 percent of the test animals. One mg/kg = 1 ppm, 1 mg = 0.000035 ounce, and 1 kg = 2.2 lbs.

MG/KG/DAY
Milligrams per kilogram of body weight per day.

MICROBIAL DECOMPOSITION
The breakdown of substances or compounds by bacteria.

MICROBIAL DEGRADATION
The breakdown of a chemical substance into simpler components by bacteria.

MICROBIOTIC ACTIVITY
The process in which bacteria and fungus interact during various ecological decay processes.

MICROORGANISM
A living organism so small it can be seen only with a microscope.

MIDDLEGROUND
The visible terrain beyond the foreground where individual trees are still visible but do not stand out distinctly from the stand.

MINORITY
Persons as specified in Directive 15, Office of Federal Statistical Policy and Standards, U.S. Department of Commerce, Statistical Policy Handbook (1978). Generally identified as one of the following four categories: Alaskan Native or American Indian, Asian or Pacific Islander, Black, Hispanic.

MITIGATION
Actions to avoid, minimize, reduce, eliminate, or rectify the impact of a management practice.

MMBF
Million board feet.

MODIFICATION
A visual quality objective meaning human activity may dominate the characteristic landscape but must, at the same time, utilize natural established form, line, color, and texture. It should appear as a natural occurrence when viewed in foreground or middleground.

MONITORING
A process to collect significant data from defined sources to identify departures or deviations from expected plan outputs.

MUNICIPAL WATERSHED
One that serves a public water system as defined in Public Law 93-523 (Safe Drinking Water Act) and associated regulations. Water for human consumption is provided for at least 25 individuals for at least 60 days per year. Forest Service management could have a significant effect on the quality of water at the intake point.

MUTAGENICITY
The capacity of a substance to cause changes in genetic material.

N

1-NAPTHOL CARBAMATE
A chemical substance derived from the natural breakdown of carbaryl and 1-napthol.

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA 1969)
An Act to declare a national policy which will encourage productive and enjoyable harmony between humans and their environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humans; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

NATURAL SPREAD
Spread of Douglas-fir tussock moth through natural means, for example young larvae carried on the wind.

NEEDLE MINER
Any insect, usually larval moths, that burrows and feeds on the interior portions of the needles of evergreen trees.

NEPA
National Environmental Policy Act of 1969, Public Law 91-190.

NEPA PROCESS
A process, mandated by NEPA, which concentrates decisionmaking around issues, concerns, alternatives, and the effects of alternatives on the environment.

NET VALUE CHANGE
The difference in value of planned resource outputs on an area before and after a fire.

NEUROTOXICITY
Quality of exerting a destructive or poisonous effect upon nerve tissue.

NFMA
The National Forest Management Act of 1976

NICHE
A habitat suitable for a particular organism and to which that organism is usually adapted.

NO ACTION
See Current Direction. Also one of four strategies used in the alternatives. No action means no interference with natural process by humans.

NOEL
No Observable Effect Level. In a series of dose levels tested, the highest level at which no effect is observed, i.e., safe in the species tested.

NOMINAL DOLLARS
A value from which the effect of change in the purchasing power of the dollar has not been removed.

NONDECLINING EVENFLOW
A harvest schedule for timber or any other resource in which the average annual harvest may increase or remain static through time but never decrease.

NONTARGET ORGANISMS
Those organisms that inhabit the treatment area in addition to the pest species being treated. These organisms could be affected by the insecticide or treatment project.

NONTHRESHOLD
A convention used in the assessment of genetic effects and carcinogens, in that no dose is sufficiently small as to assume no possible effects. In other words, an assumed safe level of exposure cannot be established. This so-called "one-hit" theory assumes that even a single molecule of a chemical may trigger a genetic response.

NOXIOUS WEEDS
Species of plants that cause disease or are injurious to crops, livestock, or land.

O

OBJECTIVE
A concise, time-specific statement of measurable planned results that respond to pre-established goals. An objective forms the basis for further planning to define the precise steps to be taken and the resources to be used in achieving identified goals (36 CFR 219.3).

OLD GROWTH
An old-growth stand is defined as any stand of trees 10 acres or greater generally containing the following characteristics: 1) stands contain mature and overmature trees in the overstory and are well into the mature growth stage; 2) stands will usually contain a multi-layered canopy and trees of several age classes; 3) standing dead trees and down material are present; and 4) evidence of human activity may be present; but does not significantly alter the other characteristics and would be a subordinate factor in a description of such a stand.

OLD-GROWTH STAND
See Old Growth

ONCOGENECITY
Refers to a genetic response that induces a cancer process.

OPPORTUNITY COST
The dollar-quantifiable net loss resulting from selecting a less efficient course of action.

ORBATID MITES
Usually scavenger mites of soil and leaf litter. They are important in promoting soil fertility through the breakdown of organic matter.

ORTHENE (R)
Commercially produced chemical insecticide formulation containing the active ingredient, acephate.

OVER MATURE
A tree that does not produce a desired level of annual growth based upon its age and past annual growth. An expression of volume, age, and growth.

OVERSTORY
The portion of trees in a forest which forms the uppermost layer of foliage.

P

PACIFIC NORTHWEST REGION
Includes the States or Oregon and Washington, portions of two Counties in California, and parts of three Counties in Idaho. The Region (sometimes called "Region 6") contains 19 National Forests and 1 National Grassland.

PARASITE
An animal that lives in or on the body of another living animal (its host), at least during part of its life cycle, feeding on the tissues of its host. Most insect parasites of other insects kill their host.

PARTICULATE
Any dispersed aggregate matter, solid or liquid (other than water), that is suspended in or falling through the atmosphere.

PASSERINE BIRDS
Birds of the Order Passeriformes (the perching birds); includes many of the insectivorous birds.

PATHOGEN
Any microorganism that can cause disease.

PERMITTEE
Holder of a permit to use National Forest land for a specific purpose.

PERORAL INTUBATION
Performed through or administered through the mouth.

PHARMACOKINETICS
The study of the action of a drug in the body over a period of time, including the process of absorption, distribution, localization in tissues, biotransformation, and excretion.

PHEROMONE
Chemical produced and emitted by female moths to attract male moths for mating.

PHOTODECOMPOSITION
The breakdown of a substance, especially a chemical compound, into simpler components by the action of radiant energy.

PHYTOPHAGOUS
Referring to plant-eating; herbivorous.

PHYTOTOXIC
Poisonous or harmful to plants.

PIONEER SPECIES
A plant capable of invading bare sites (e.g., a newly exposed soil surface) and persisting there, i.e., "colonizing" them, until supplanted.

PLANT COMMUNITIES
A vegetation complex, unique in its combination of plants, which occurs in particular locations under particular influences. A plant community is a reflection of integrated environmental influences on the site; i.e., soils, temperature, elevation, solar radiation, slope, aspect, and rainfall.

PLECOPTERA
Stoneflies. Group of insects, the nymphs of which are aquatic and mostly phytophagous.

PNV
See Present Net Value.

POLICY
A guiding principle upon which a specific decision or set of decisions is based.

POPULATION DYNAMICS
The study of changes and the reasons for changes in population size.

PPB
Parts per billion; the number of parts of a substance in question per billion parts of a given material. One ppb = 1 ug/liter (water or air).

PPM
Parts per million; the number of parts of a substance in question per million parts of a given material. (1 ounce of salt in 62,500 lbs of sugar). One ppm = 1 mg/kg (on a weight basis) = 1 mg/liter (water or air).

PRECOMMERCIAL THINNING
Any type of thinning that takes place in a stand of trees before the size or condition of the material cut or killed makes it of sufficient value to meet the costs of the activity.

PREDATOR
An animal that preys on others.

PRESCRIBED BURNING
Intentional application of fire to forest or rangeland in a natural or modified state to meet specific management objectives.

PRESCRIPTION (SILVICULTURAL)
The formal written plan of action to carry out a silvicultural treatment of a forest stand to achieve specific objectives.

PRESENT NET VALUE
The difference between the discounted values (benefits) of all outputs to which monetary values or established market prices are assigned, and the total discounted costs of managing the planning area (36 CFR 219.3).

PRESENT NET WORTH
See Present Net Value.

PRESERVATION (VISUAL)
See Visual Quality Objective.

PROBABILITY
A number expressing the likelihood of occurrence of a specific event, such as the ratio of the number of experimental results that would produce the event to the total number of events considered possible.

PROGRAMMED HARVEST
Timber scheduled for harvest for a specific year.

PROIMAL (TUBULES)
Nearest; closer to any point of reference. Opposite of distal.

PUBLIC BENEFITS
Any output which is perceived as beneficial by citizens of the United States.

PUBLIC ISSUE
A subject or question of widespread public interest relating to management of the National Forest System (36 CFR 219.3).

PUPA (PLURAL PUPAE)
The immobile, transformation stage in the development of an insect that, as an adult, is completely different in its appearance compared to what it looked like when it hatched from its egg. Examples include beetles, flies, moths, and wasps.

R

RAPTORS
Birds of prey including hawks, eagles, falcons, and owls.

RATE-OF-RETURN
The annualized net profit on an investment, expressed as a percentage.

REAL DOLLAR VALUE
A monetary value which compensates for the effects of inflation.

RECREATION OPPORTUNITY
An opportunity for a user to participate in a preferred activity within a preferred setting in order to realize those satisfying experiences which are desired.

REDD
In anadromous fishes - the depression formed in the stream bottom in which the eggs are deposited.

REFOLIATION
Term used to describe a new flush of leaves in mid-season.

REFORESTATION
The natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial restocking.

REGENERATION
The renewal of a tree crop, whether by natural or artificial means. Also the young tree crop itself.

REHABILITATION
A short-term management alternative used to return existing visual impacts in the natural landscape to a desired visual quality.

REINVASION
The movement of an organism from adjacent populations back into an area where the organism has been excluded.

RELIEF
The departure of the land surface in any area from level ground.

RENAL
Pertaining to, or in the region of, the kidneys.

RESEARCH NATURAL AREA
An area, typifying an important forest, shrubland, grassland, alpine, aquatic, or geologic type, or other natural situation that has special or unique characteristics which is set aside to provide a benchmark for education and research.

RESEARCH RELEASE AREAS
Area of land used in studying the establishment of parasites that were released as a biological control for an insect pest such as the larch casebearer.

RESIDUAL
Refers to remaining.

RESIDUAL STAND
The trees remaining standing after some form of selection cutting is performed on a stand.

RESORPTIONS
To absorb again. In biology it means to dissolve and assimilate.

RESURGENCE
The growth of a population back to pre-treatment levels from a resident population.

RIPARIAN HABITAT
That portion of a watershed or shoreline influenced by surface or subsurface waters, including stream or lake margins, marshes, drainage courses, springs, and seeps.

RIPARIAN VEGETATION
Nonaquatic vegetation found within riparian areas. Typically, this vegetation is dependent upon a seasonally high water table.

RIPARIAN ZONES
The transitional zone located between the terrestrial and aquatic zones. This stream-adjacent area contains plants, animals, and soil types specific to this area.

RISK
The degree and probability of loss based upon chance.

RISK ASSESSMENT
An analytic process that is firmly based on scientific considerations, but also requires judgments to be made when the available information is incomplete. These judgments inevitably draw on both scientific and policy considerations.

RISK CHARACTERIZATION
Describes the nature and magnitude of the human risk. Risk characterization uses the information gathered in other stages to represent the overall situation. The assessment of toxicity, along with levels and probability of exposure, are joined to estimate risk.

RISK MANAGEMENT
The process of weighing policy alternatives and selecting the most appropriate regulatory action, integrating the results of risk assessment with engineering data and with social, economic, and political concerns to reach a decision.

S

SAFETY FACTOR
A factor conventionally used to extrapolate human tolerances for chemical agents from "No Observed Effect Levels" in animal test data.

SALMONOID FISH
Fish having salmon-like characteristics - includes the trouts, salmons, and whitefish.

SCENIC AREAS
Places of outstanding or matchless beauty which require special management to preserve these qualities. They may be established under 36 CFR 294.1 whenever lands possessing outstanding or unique natural beauty warrant this classification.

SCOPING
An integral part of environmental analysis. Scoping entails: Examining a proposed action and its possible effects; establishing the depth of environmental analysis needed; and determining analysis procedures, data needs, and task assignments.

SCOPING PROCESS
A process in conjunction with environmental analysis which identifies issues and concerns that are within the authority of the Forest Service to resolve.

SCOPING SESSION OR ACTIVITIES
As defined under the National Environmental Policy Act - an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action. This may include public meetings whereby significant issues are identified, or may simply be letters of inquiry to interested agencies, groups, or individuals.

SECOND GROWTH
Forest growth that has come up naturally after some drastic interference with the previous forest growth; e.g., cutting, serious fire, or insect attack.

SENSITIVE SPECIES
Those species of plants or animals that have appeared in the Federal Register as proposed for classification and are under consideration for official listing as endangered or threatened species, that are on an official State list, or that are recognized by the Regional Forester as needing special management to prevent their being placed on Federal or State lists.

SERAL
A biotic community which is a developmental, transitory stage in an ecologic succession.

SEVIN 4 OIL (R)
Commercial insecticide formulation containing the active ingredient carbaryl.

SEVIN 80 S (R), SEVIN SPRAYABLE (R), SEVIN XLR (R)
See Sevin 4 Oil.

SHADE-INTOLERANT TREES
Trees which reproduce successfully only in the open or where the canopy is greatly broken.

SHADE-TOLERANT TREES
Trees which reproduce and form understories beneath canopies of less tolerant trees or even beneath shade of their own species.

SILVICULTURAL SYSTEM
A management process whereby forests are tended, harvested, and replaced, resulting in a forest of distinctive form. Systems are classified according to the method of carrying out the fellings that remove the mature crop and provide for regeneration, and according to the type of forest thereby produced.

SITE PRODUCTIVITY
Production capability of specific areas of land to produce defined outputs such as AUMs, cubic feet/acre/year, etc.

SLASH
The wood residue left on the ground after timber cutting and/or accumulating there as a result of storm, fire, or other damage. It includes unused logs, uprooted stumps, broken or uprooted stems, branches, twigs, leaves, bark, and chips.

SLOPE
An inclined ground surface in which the inclination is expressed as a ratio of horizontal to vertical distance. The face of an embankment or cut section.

SMALL GAME
Birds and small mammals typically hunted or trapped.

SNAG
A standing dead tree.

SOCIAL ORGANIZATION
The structure of a society described in terms of institutions, community cohesion, and community stability.

SOCIOECONOMIC
Pertaining to, or signifying the combination or interaction of, social and economic factors.

SOIL
The unconsolidated mineral and organic material on the immediate surface of the earth.

SOIL RESOURCE
A product of the interaction of parent materials, vegetation, climate, and relief over time; it is a nonrenewable resource.

SPAWNER
An anadromous fish returning to fresh water for purposes of egg-laying or fertilization of eggs.

SPORE
Any small cell that can regenerate into a new individual.

SPREADER/STICKER AGENT
Substances that are added to the spray tank, separate from the pesticide formulation, that improve the performance of the pesticide. Spreader causes the formulation to spread out more to increase coverage; sticker increases the adhesion or "stickiness" of the pesticide.

STAND
Timber possessing uniformity to type, age class, risk class, vigor, size class, and stocking class.

STANDARD
A principle requiring a specific level of attainment; a rule against which to measure.

STATISTICAL SIGNIFICANCE (EXPRESSED AS A CONFIDENCE LEVEL)
A statistical term expressing confidence that results obtained from an experiment did not occur by chance. For example, a 95-percent confidence level says there is a 95-percent probability results obtained were due to conditions of the experiment and a 5-percent probability they were due to chance.

STOCKING LEVEL
A measure of the existing number of trees in a stand in relation to the number desired for optimum growth and volume.

STRATEGY
A carefully planned course of action. Four strategies are incorporated into the alternatives presented, no action, prevention, correction, and maintenance.

SUBACUTE
The effects observed from doses of intermediate duration, usually three months.

SUCCESSIONAL PROGRESSION
The process in which ecological change from one community, such as seedlings, progress toward an old-growth community.

SUCCESSIONAL STAGE
A stage or recognizable condition of a plant community which occurs during its development from bare ground to climax.

SUITABILITY
The appropriateness of applying certain resource management practices to a particular area of land, as determined by an analysis of the economic and environmental consequences and the alternative uses foregone. A unit of land may be suitable for a variety of individual or combined management practices.

SUITABLE
See Commercial Forest Land.

SUMMER RANGE
A portion of the total range on which big-game animals normally find food and cover during summer months.

SUPPLY
The amount of an output producers are willing to provide at a specific price, time period, and condition of sale.

SUPPRESSION PROJECTS
Projects administered by the USDA Forest Service, in cooperation with State or other Federal agencies, designed to relieve high western spruce budworm populations in high-value or high-use areas.

SWATH WIDTH
Area on the ground in which the amount of spray equals or exceeds the amount determined to provide effective control.

T

TECHNIQUE
How a basic method is used.

TERATOGENICITY
The capacity of a substance to cause anatomical, physiological, or behavioral defects in animals exposed during embryonic development.

THERMAL COVER
Vegetation that provides wildlife a sheltering effect from climatic conditions.

THINNING
A felling made in an immature tree crop or stand in order to primarily accelerate diameter increment. Also, by suitable selection, to improve the average form of trees that remain, without, at least according to classical concepts, permanently breaking the canopy.

THREATENED SPECIES
Any species listed in the Federal Register, which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

THRESHOLD
This is the point on a dose-response curve, above which effects occur and below which no effects occur.

THURICIDE (R)
Commercial biological insecticide formulation containing the active ingredient, *Bacillus thuringiensis*.

TIERING
Refers to the coverage of general matters in broader environmental impact statements (such as National program or policy statements) with subsequent narrower statements or environmental analyses (such as regional or basinwide program statements or, ultimately, site-specific statements) incorporating by reference the general discussions and concentrating solely on the issues specific to the statement subsequently prepared.

TIMBER PRODUCTION
The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use. For purposes of this definition, the term "timber production" does not include production of fuelwood.

TOLERANCE
Forestry term for expressing the relative capacity of a tree to compete under low light and high root competition.

TOTAL SUSPENDED PARTICULATE MATTER (TSP)
Amount of particulate materials of all sizes (mass basis) suspended in a unit volume of the atmosphere at a point in time.

TOXIC
Relating to a harmful effect by a poisonous substance on the human body by physical contact, ingestion, or inhalation.

TOXICANT
A poison; toxic agent.

TOXICOLOGIC HAZARD IDENTIFICATION
Determines whether or not a particular chemical is causally linked to an adverse health outcome.

TOXICOLOGY
The study of the nature, effects, and detection of poisons and the treatment of poisoning.

TRANSITORY RANGE
Land that is suitable for grazing use of a nonenduring or temporary nature over a period of time. For example, on particular disturbed lands, grass may cover the area for a period of time before being replaced by trees or shrubs not suitable for forage.

TRANSPORTATION CORRIDOR
Routes designated for ground transportation of equipment and insecticides to and from project staging areas.

TRICHLORFON (R)
Active ingredient found in chemical insecticide formulations sold under the trade name, Dylox (R).

TRUE FIR
Those species of trees such as white, silver, and grand fir located on high-elevation soil sites. A specific ecological plant community.

U

UNCERTAINTY
May be due to missing information, or gaps in scientific theory. Whenever uncertainty is encountered, a decision, based upon scientific knowledge and policy considerations, must be made. The term, scientific judgment, is used to distinguish this decision from policy decisions made in risk management.

UNDERSTORY
Vegetation growing under a higher canopy.

USDA
United States Department of Agriculture.

USDI
United States Department of the Interior.

V

VALUE, MARKET
The unit price of an output normally exchanged in a market after at least one stage of production, expressed in terms of what people are willing to pay as evidenced by market transactions.

VALUE, NONMARKET
The unit price of a nonmarket output not normally exchanged in a market at any stage before consumption, and thus must be imputed from other economic information.

VARIETY CLASS
A classification system for establishing three visual landscape categories according to the relative importance of the visual features.

VEGETATIVE REGENERATION
The process in which plants and/or vegetative matter establish a presence on a disturbed site.

VERTEBRATES
Those organisms having a spinal column protected by bone or cartilage.

VIEWSHED
The total landscape seen, or potentially seen, from all or a logical part of a travel route, use area, or water body.

VIRAL ENHANCEMENT
Ability to enhance the activity of viruses which are minute infectious agents characterized by a lack of independent metabolism and by the ability to replicate only within living host cells.

VISIBILITY
How far a given object can be seen by the human eye. The greatest distance in a given direction at which it is just possible to see and identify with the unaided eye in the daytime, a prominent dark object and, at night, a known, preferably unfocused, moderately intense light source.

VISUAL MANAGEMENT SYSTEM
The management system used to protect and enhance the visual resource.

VISUAL QUALITY OBJECTIVE
A combination of inherent scenic quality and public interest which defines the acceptable degree of alteration for any given area.

VISUAL RESOURCE (FOREST SCENERY)
The composite of basic terrain, geologic features, water features, vegetative patterns, and land use effects that typify a land unit and influence the visual appeal the unit may have for visitors. Visual resource categories include Retention (R), Partial Retention (PR), and Modification (M).

VOLATILIZATION
The changing from a solid state to a vaporous state.

W

WATERSHED
The area drained by a river or river system.

WETLANDS
Those areas that are inundated by surface or ground water with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetation or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Wetlands generally include swamps, marshes, bogs, and similar areas such as sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds.

WILDERNESS
Lands designated by law as wilderness; no road building or timber harvesting is allowed on such lands; they are intentionally managed to maintain their primitive character.

WILDFIRE
Any wildland fire that requires a suppression response.

WINTER RANGE
A range, usually at lower elevation, used by migratory deer and elk during the winter months.

WORST CASE (EXPOSURE)
In the context of this analysis, the worst-case exposure has been defined by adding two standard deviations to the mean exposure. This will set the exposure for a worst-case scenario at the 95-percentile level. Depending upon the variability of the data being analyzed, or the dispersion of values around the mean value, this typically will increase the average exposure levels several times over. For example, the realistic exposure to the general public through drift off-site is 0.00006 mg/kg/day, while worst case is 0.0003 mg/kg/day or 5 times the realistic dose. (Spill and accident situations are defined separately).

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